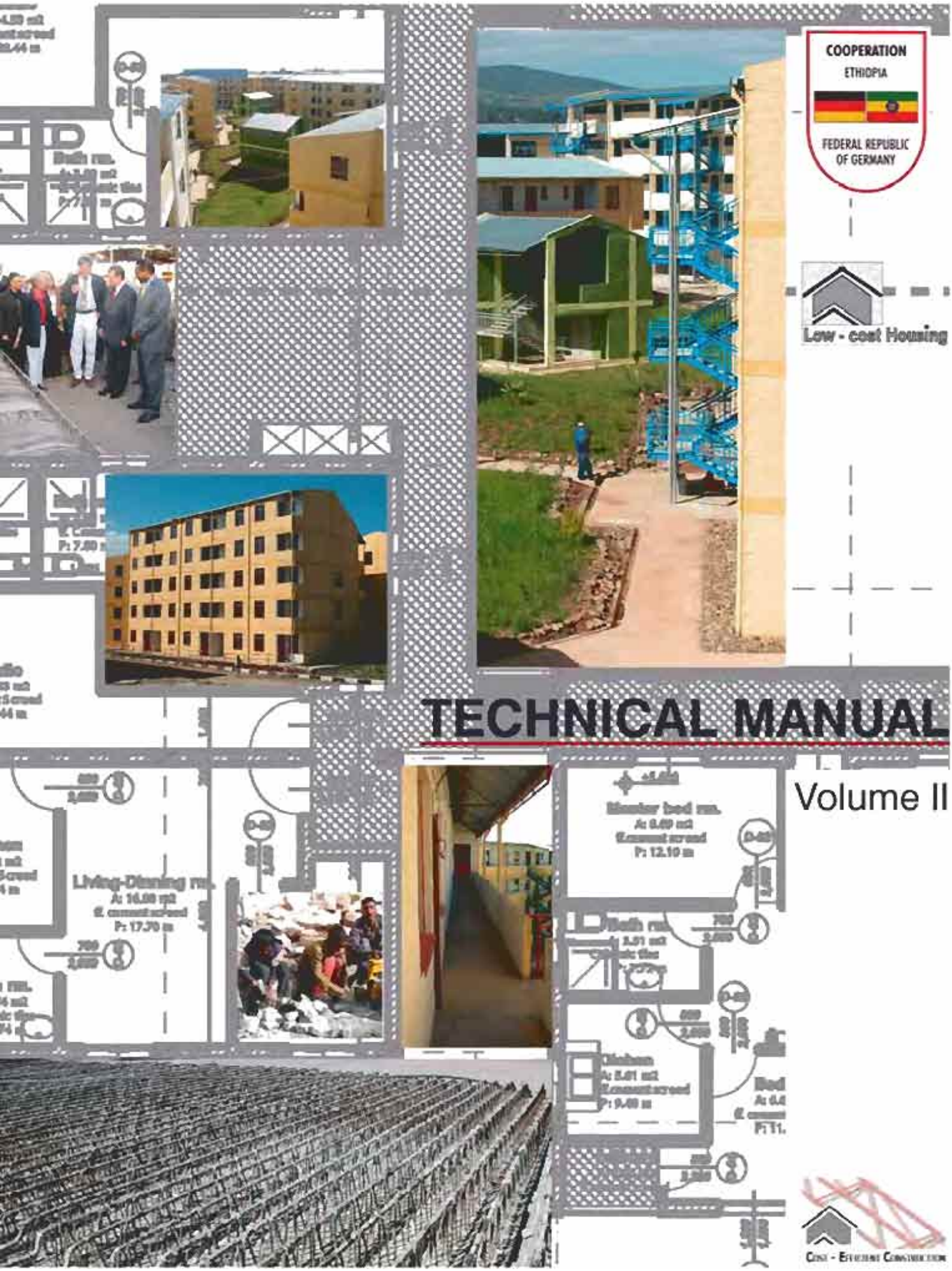
COOPERATION
ETHIOPIA
FEDERAL REPUBLIC
OF GERMANY
Low - cost Housing
TECHNICAL MANUAL
Volume II
Living-Dining rm.
Master bed rm.
Cost - Efficient Construction

Ministry of Federal Affairs

Addis Ababa City Government

Addis Ababa Housing Development Project Office

Deutsche Gesellschaft für
Technische Zusammenarbeit (GTZ) GmbH

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Illustrations and layout:
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Addis Ababa, Ethiopia, April 2005

"The Bole/Gerji Apartments Construction Project" is the "pilot" for the Addis Ababa Grand Housing Program.

It demonstrates - in a nutshell - best practices in:

- Densification & vertical growth
- Conducive neighbourhood with communal facilities & greeneries
- Mixed functions & socio-economically mixed population composition
- High quality construction, cost-efficient m^2 price, environmentally friendly approach, short construction period
- Timely basic infrastructure provision.

Thousands of workers have been employed and trained during construction time and more than 85 micro- and small enterprises have been involved and promoted.

The Bole/Gerji Apartments Construction Project lays the basis as **"learning and training ground"** for the Addis Ababa Grand Housing Program aiming at constructing up to 50.000 housing units per year, creating 40.000 jobs and employing 1500 micro and small enterprise .

The Addis Ababa Grand Housing Program diversifies and professionalizes the Ethiopian construction sector improving the quality of construction while at the same time reducing its costs. It moreover mobilizes the economy, as the construction sector is known to be the motor of economic development. The promotion of private initiatives is the main goal. It governs the approach in a combination with overall capacity building aiming at the human resources on all levels.

The Addis Ababa Grand Housing Program makes housing for the first time accessible for low and middle urban income dwellers. It enables them to acquire decent shelter to raise their children in a healthy environment improving their overall living conditions.

The GTZ/Low-cost Housing Project, supported by the German Government, in collaboration with MH-Engineering P.L.C. has introduced a cost-efficient and environmentally friendly construction technology resulting in a considerable cost reduction per m^2 construction.

At present 45.000 housing units are under construction in Addis Ababa. Urban renewal and slum upgrading programs are being prepared ready for implementation in order to complement the newly constructed housing schemes.

Addis Ababa is undergoing a massive

renovation and rejuvenation process in order to cope with the challenges of becoming the “Capital of Africa” in the first urban African century.

A successful integrated construction program will end up in a win-win situation for:

- the residents of Addis Ababa
- the private sector
- the international community
- the achievement of the internationally agreed upon Millennium Development Goals (MDGs).

Let’s join hands in this common effort!

The Mayor of Addis Ababa
H.E. Ato Arkebe Oqubay

Addis Ababa, Ethiopia, April 2005

Impressions from the Bole Gerji site

Impressions from the Bole Gerji site

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Structural design of low cost apartments 40

The Technical Manual, Volume II, is a continuation of the first Technical Manual published by the GTZ/Low-cost Housing Project in 2003. The objective of the new Manual is, to inform about the development of Low-cost housing in Ethiopia. In this context, the following issues will be treated:

- The Addis Ababa Grand Housing Program,
- Its implications in regard to training-on-the-job, micro and small enterprise promotion and employment generation,
- The Bole/Gerji Pilot Apartment construction site,
- The service package "Cost-efficient housing in the framework of integrated urban development planning",
- The organizational structures required,
- Examples of new neighborhood & housing designs (apartment buildings),
- LCH - MH Technology,
- Structural design requirements for low cost apartments.

Moreover, the Manual includes a construction guideline "Step by step" meant to support site supervisors and site engineers to organize construction sites and control the quality as well as the implementation of the technical requirements. It is a very practical guide including check lists for the different tasks to be accomplished. It starts with excavation & earthwork and ends with slab construction, thus going through the whole construction process with its most important corner stones.

The overall target groups for this Manual are:

- Architects,
- Engineers,
- Construction contractors,
- Bilateral and Multinational Development Agencies and
- Politicians who want to improve urban Ethiopia.

1. Background

The shortage of housing is among the most visible problems of poverty in Addis Ababa. 3 millions out of the total population of 4 millions are living in overcrowded houses or dilapidated structures, under unhygienic conditions, lacking basic urban services like safe drinking water and sewage, and in sprawling informal settlements with a growing number of shacks.
85% of the housing structures in Addis Ababa are dilapidated and would have to be demolished or rehabilitated in a costly manner. They are in their majority without the minimum basic infrastructure such as flushing toilets and connection to the sewer system.
An estimated 80% of the 150.000 Kebele houses[1] have serious problems of maintenance and are in a very bad shape.
Up to 50% of the population is without fixed employment.
The accumulated housing backlog is estimated to be 300.000 units.
Moreover, 60.000 units are needed to accommodate the population increase of 7 -8% p.a.- mainly a result of migration from the rural areas.
In order to solve the housing deficit, the Addis Ababa City Government has launched an ambitious "Addis Ababa Grand Housing Program" with the objective to construct up to 50.000 housing units per year. The aim of this program is to provide low and middle urban income dwellers with decent shelter. At the same time the housing programs aims at promoting micro and small enterprises, implementing training – on – the – job, mobilizing the saving potential and diversification of the construction sector. The overall impact is a boost to the economy as the construction sector is the motor for economic development.
The Addis Ababa City Government additionally plans to upgrade and renew the inner City of Addis Ababa transforming Addis Ababa into the "Capital of Africa".
The Bole/Gerji Apartment Construction Project is considered to be the "Pilot" for the Addis Ababa Grand Housing Program.

2. Rationale

The Addis Ababa Grand Housing Program is to be seen within the internationally agreed upon Millennium Development Goals intending to:

- reduce poverty by 50% in 2015,
- improve the life of 100 million slum dwellers by 2020,
- provide access to sanitation to 50% of the currently unserved population by 2015 and 100% reliable service to all by 2025.

The Global Monitoring Report 2004 of the World Bank and the International Monitory Fund has stated that poverty efforts must be accelerated through more investment in infrastructure in order to reach the Millennium Development Goals.

Footnote:

[1] Houses owned by the Government since 30 years. They have not been repaired nor maintained, as the rent being paid by the actual occupants is very low.

Large-scale housing programs create employment, purchasing power and activate the economy.

Ethiopia has committed herself to these goals. Addis Ababa is implementing large infrastructure investment programs in the housing sector for new construction as well as for slum upgrading and renewal in order to improve the living conditions of the urban poor.

Moreover, housing has been universally accepted as the second most important human need after food.

The Habitat II Conference in Istanbul (1996) has (re-) confirmed the right of decent shelter for all human beings.

Housing is the "key" to become a human being, the "key for empowerment".

Housing protects children and females from harassment.

Well-constructed housing protects in case of natural disasters and turmoil.

3. Concept of Bole/Gerji Pilot Apartments Construction Site

Bole/Gerji Pilot Apartments Construction Project consists of 700 cost-efficient apartments in a conducive neighbourhood with 28 buildings including one commercial building, communal facilities such as traditional kitchens, slaughterhouses, laundries, storage facilities and green areas.

The Bole Gerji Housing Scheme was inaugurated on July 17, 2004 by the Prime Minister of Ethiopia after only eight months of construction.

The Bole/Gerji Pilot Project is the pilot for cost-efficient, economical and hence affordable apartment buildings within a pleasant neighbourhood.

The Bole/Gerji construction scheme for housing and commercial activities is to demonstrate "best practices" in regard to an integrated approach of:

- training – on – the – job,
- micro and small enterprise promotion (MSE),
- diversification and professionalisation of the construction sector,
- mobilization of savings ,
- timely provision of basic infrastructure.

Micro and small enterprise promotion

Bole/Gerji contributed to income generation and increased purchasing power:

Up to 2500 workers have been employed daily on Bole/Gerji earning some decent money to improve the living conditions of their families hence activating the local economy.

On the Bole Gerji production site, up to 750 workers were daily engaged in the production of hollow-concrete blocks. The majority of them (75%) were female workers.

86 micro enterprises supplied Bole/Gerji with metal doors and windows.

The electrical & sanitary installation within the buildings was done by specialized micro and small companies, some of them newly created.

Densification/vertical growth

Bole/Gerji Apartment Construction is also a pilot for densification, vertical growth, cost-efficient and cost-effective building technologies on the basis of cost-efficient and cost - effective designs without sacrificing aesthetics.
All designs and buildings are based on the Ethiopian Building Code also considering that Addis Ababa falls within the earthquake zone 3.

Conducive neighbourhood with basic infrastructure

A new form of neighbourhood plan delineated from the beginning the basic infrastructure to be installed including the main lines for water, a decentralized sewer system, electricity, telephones, roads, pavement, walkways, greeneries and communal facilities such as slaughterhouses, traditional kitchens, laundries and additional storage rooms.
The "pilot" Bole/Gerji, composed of a socio-economically mixed population and mixed functions, is considered to be a "learning and training ground" for the Addis Ababa Grand Housing Program.

Training – on – the - job

The training of semi- and skilled labourers, trainees and trainers in the essential construction trades as well as small and micro enterprise promotion was a priority activity during construction, however, not neglecting but even emphasizing quality control and quality assurance in construction. Training concentrated on a "hands-on" approach, i.e. practical training on the job was exercised in the different relevant trades in construction, in greenery planning and implementation as well as in roads, sewer, drainage, pavement and walkway construction.

Cost-efficient technology

Financially viable and technologically sound construction solutions on the basis of pre-fabricated elements have been demonstrated, applied, trained and multiplied to make the approach sustainable and replicable. This "pilot" will strongly contribute to show solutions how to significantly reduce the housing and basic infrastructure shortage in Addis Ababa as well as in other urban centers of Ethiopia in an appropriate and cost-effective manner with a defined high quality.
The m² price for construction is below Birr 900 (EUR 90)[2] although Bole/Gerji is built on aggressive black cotton soil[3] increasing the costs for foundation work.
The buildings have been built in a manner to minimize major repair and maintenance costs for the next ten years.

Footnotes:

[2] Birr 868.59

[3] Black cotton soil is expansive soil that accumulates four times of its own weight when coming into contact with water.

4. Location & Site

Bole/Gerji site is located in Bole Sub-city (Bole Kifle Ketema), Kebele 11 of Addis Ababa. The construction site consists of 45,191m² with an adjacent production site of 12,000 m².

The built-up area amounts to 47,060 m².

The densification rate is 700 persons/ha.

In detail, the Bole/Gerji settlement plan consists of 28 buildings type:

- A (G+ 3; 6 buildings),
- B (G+3/4; 3 buildings),
- C (G+3; 12 buildings),
- D (G+3; 6 buildings),
- E (G+3/4;1 commercial building) and
- F (communal facilities such as 32 communal kitchens, 7 laundries, 7 slaughter units, 100 storage provisions).

696 apartments of different sizes varying from 22 m² up to 105 m² are made available within a conducive neighbourhood:

- 20.69 % (No. 144) apartments are studio type (22,02 - 26,43 m² each),
- 35.78 % (No. 249) apartments are single bedroom type (40,59 - 54,63 m² each),
- 41.81 % (No. 291) apartments are double bedroom type (63,26 - 82,78 m² each),
- 1.72 % (No. 12) apartments are three-bedroom type (105,04 m² each).

5. Implementing Agency

GTZ International Services (GTZ IS) is the Implementing Agency.

GTZ International Services (GTZ IS)

The GTZ is an international cooperation enterprise for technical assistance, owned by the Federal Republic of Germany. It is a public benefit organization not aimed at making profits. Profits (if any – e.g., reserves which were not required to cover liability risks) may not be distributed to GTZ' shareholder (the German Government), but must be spent for development projects. According to its statute, GTZ's objective is to assist the German Government in achieving its development goals.

The Consultant MH-Engineering P.L.C. was responsible for supervision in collaboration with the GTZ/Low-cost Housing Project (LCH) giving advisory service.

MH ENGINEERING P.l.c.
Consulting Engineers

6. Neighbourhood, architectural, sanitary, electrical & structural designing

The designs for the Bole/Gerji Project have been elaborated by Ethiopian consultants such as MH-Engineering, Ato Fasil Giorghis, Ato Elias Yitbarek, Geretta Consult, SAN-MECH CONSULT & FASTEK CONSULT in collaboration with the GTZ/LCH.

Dr. Messele Haile/MH-Engineering holds responsible for the structural design.

MH ENGINEERING P.l.c.
Consulting Engineers

7. Future plans

20 more sites with totally 20.000 apartments within Addis Ababa have been designed by GTZ/LCH in collaboration with MH-Engineering.
GTZ IS is implementing the construction on these 20 sites in collaboration with different subcontractors and micro and small enterprises.
The sites will be completed within 8 to 12 months.
100 other sites with totally 66.000 apartments are being implemented by the Addis Ababa Housing Development Project Office (AAHDPO) in collaboration with MH-Engineering and GTZ/LCH.
GTZ/LCH has prepared the neighbourhood, architectural, sanitary and electrical designs for Gotera with 137.000 m^2 (3436 housing units) and Gofa (8000 housing units).
The Addis Ababa Plan Commission has prepared the Local Development Plan for Gofa with 45 hectare. Up to 7800 housing units, i.e. a new town of roughly 40.000 inhabitants, will be accommodated in Gofa after completing the designs by GTZ/LCH and MH-Engineering and implementing construction by GTZ IS and the AAHDPO in the near future.

Information on the service package

"Cost-efficient housing in the framework of integrated urban development planning"

Thematic areas; General explanation and background, framework conditions & relevance

Integrated approach to reduce poverty[1] through promotion of economic development , in particular of the construction sector as motor of economic development.

Integrated cost-efficient housing has become the priority for the development of urban Ethiopia. Addis Ababa City Government has approved an action program for the promotion of housing construction for middle and lower income groups enjoying highest political priority.

Mass housing construction is to take place through pro-active micro- and small enterprise promotion, improvement of the performance of the construction sector through specialization, training – on – the – job and mobilisation of the saving potential of the beneficiaries.

The employment of thousands of unemployed youths , the promotion & creation of micro- and small enterprises, skills upgrading training of construction site management staff down to construction workers and the specialization of construction industry to construct decent shelter is the main investment program of the Addis Ababa City Government.

Contents/Concept

The planning & implementation of integrated cost-efficient housing programs is a comprehensive, multisectoral system approach consisting of the following components of urban development planning & economic promotion:

Footnote:

[1] Millennium Development Goals (MDG); the World Bank and the IMF recommend increased investment in comprehensive infrastructure programs in order to reach the MDG.

Cost-efficient densified provision of housing in the framework of structured urban development planning with pro-active participation of the private sector.

Introduction of innovative & environmentally friendly neighborhood, architectural, structural, sanitary & electrical designs as well as their implementation.

The settlements follow the concept of socio-economic mixture and mixed functions. The housing units dispose of electricity, water supply and sanitation , access & internal roads (physical basic infrastucture), social infrastructure and communal facilities to ease getting used to modern urban dwelling structures.

Advisory service to the utilities and Municipslities to achieve a timely provision of basic infrastructure for the settlements (reduces costs).

Construction on urban in-fill areas has priority against construction on the outskirts of the cities to avoid urban sprawl and economize on the costs for basic infrastructure provision.

Newly formed neighborhoods are given advisory service to form groups/associations to take care of the repair & maintenance works of the buildings, the communal facilities, roads, walkways, organize the emptying of the septic tanks, etc.

A recently elaborated “Federal Urban Planning Law” and a Building Law (both presented to Parliament) will enhance structured urban development initiated and supervised by the Municipalities encouraging private sector investment and development.

The reduction of the m^2 price for construction by 40-50% (Birr 800 – Birr 900 ; € 80 to 90) depending on the location, soil conditions/earthquake zone and type of building (on the basis of the Ethiopian Building Code) makes housing accessible to lower and middle income groups for the first time.

The dissemination of the cost-efficient technology takes place by training and cooperation with the Ethiopian construction sector, i.e. consultants & contractors.

The local banks are releasing credits for the first time for housing including apartments to individual beneficiaries of the lower segments of society on the basis of title deeds. The interest rates are based on market conditions. The pay back discipline is very high – there are no defaultees up to now.

Advisory service to build up sustainable efficient structures for the planning & implementation of cost-efficient integrated housing programs.

Income & job generation through:

- Diversification of the construction industry through specialization within the construction trades such as electrical installation, sanitary installation, masonry, reinforcement/concrete/ barbender, roofing, ceramic tile laying, road maker, etc.
- Employment of construction workers on construction sites,
- Promotion of suppliers linked to the construction sector (forward and backward linkages) such as metal door, metal window, girders, hollow concrete blocks , furniture suppliers).

Training – on – the – job on all levels:

- Semi- and skilled construction workers, formen,
- Construction site management staff.

Mobilisation of saving potential of future house/apartment owners.

Users of the service package

Municipalities with economic problems and a huge housing deficit.

Impact

The service package enables the Municipalities to:
Implement cost-efficient densified housing construction on the ba-

sis of integrated & structured urban development planning combined with income & job promotion & training – on – the – job in the framework of regional economic promotion.

Achieve an increase of their income through taxes and fees.

Direct benefits:

- Reduce unemployment, in particular of young people
- Micro and small enterprise promotion & creation.
- Increased income through taxes & fees.
- (Re-) activation of the economy.
- Diversification and professionalisation of the construction sector.
- Creation of value chain in the construction sector.
- Skills upgrading training.
- Mobilization of saving potential and integration into the economic/financial circulation process.

Indirect benefits:

- Improve the efficiency & effectiveness of urban services.
- Create conducive environment for private investment.
- Create confidence in governmental structures.
- Promotion of good governance.
- Win-win situation.

Context

The service package has been implemented in eight Municipalities of Ethiopia. In Addis Ababa, the capital of Ethiopia, 45,000 housing units are at present under construction on the basis of the service package described above.

Costs

Between Birr 800-900, i.e. EUR 80 –90 per m^2 construction

In order to implement ambitious housing programs functional & efficient organizational structures have to be created for a defined period. The organizational structures should be established in the form of a "Project/Program" or "Task Force" outside of the bureaucratic structures of the civil service. The "Project" should allow utmost flexibility in regard to contracting, procurement, finance and recruitment of staff. A conducive salary structure should allow for professional and motivated staff to be contracted and for good performance to be awarded. The people recruited should know the existing governmental and municipal structures, roles and functions in order to avoid timely learning curves and in order to address the right person in case of problems.

The "Project" should have a lean and horizontal structure avoiding limiting vertical hierarchies as far as possible.

However, internal and/or external auditing would have to be performed annually in order to avoid mismanagement.

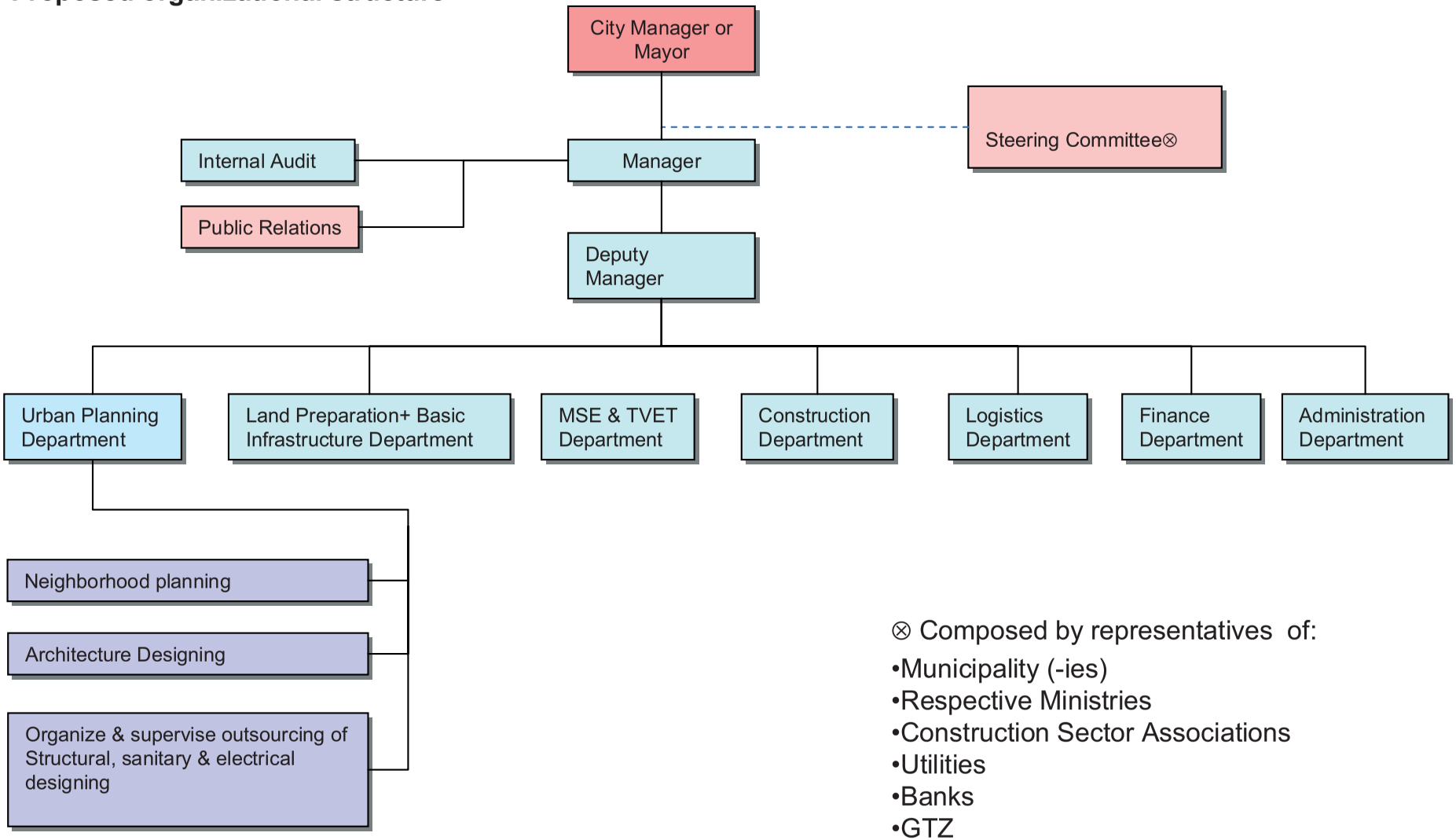
The proposed organizational structure below indicates the major functions/departments to be considered for integrated housing programs.

The "Project" in particular would have to take over a supervisory function in regard to negotiations with the contractors & subcontractors and in regard to organizing quality control and capacity building. The designs have to be presented to the contractors by the "Project" on the basis of detailed specifications and BOQ. Thorough negotiations should concentrate on the financial offers coming in through tenders in order to check overhead costs & profit margins. The overhead costs & profit margins nowadays experienced might have to be rechecked and renegotiated if the Government is firm in its conviction to implement massive housing programs for middle and lower urban income groups.

The promotion of specialized subcontractors supports the reduction of costs and improves quality through mutual control. It also reduces dependency on few (big) contractors.

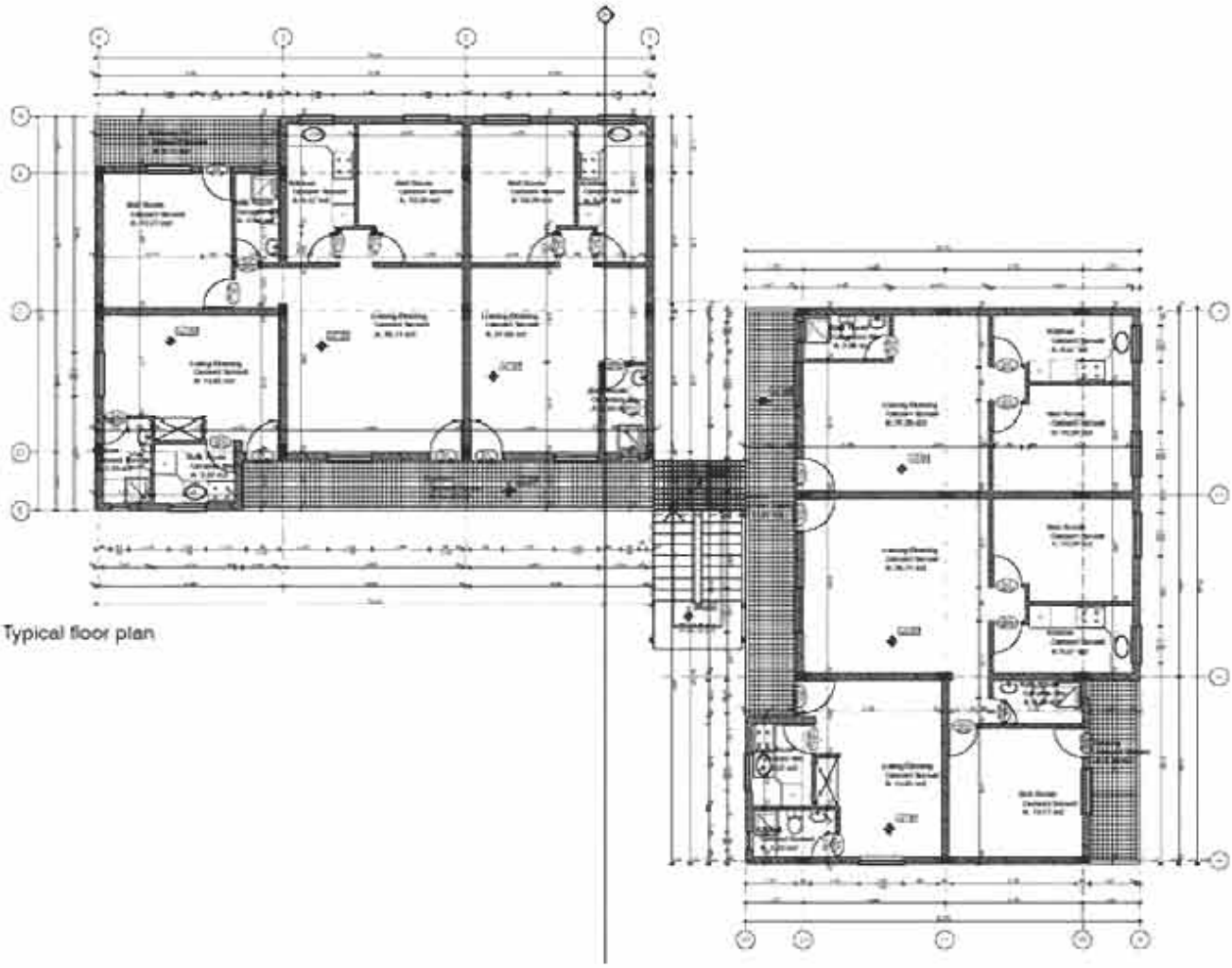
A new relation based on the spirit of partnership, supervision and capacity building should be introduced in order to cope with the noble task of ambitious and comprehensive housing programs providing decent shelter for lower urban income groups. This partnership should be "solution oriented".

Proposed organizational structure



⊗ Composed by representatives of:

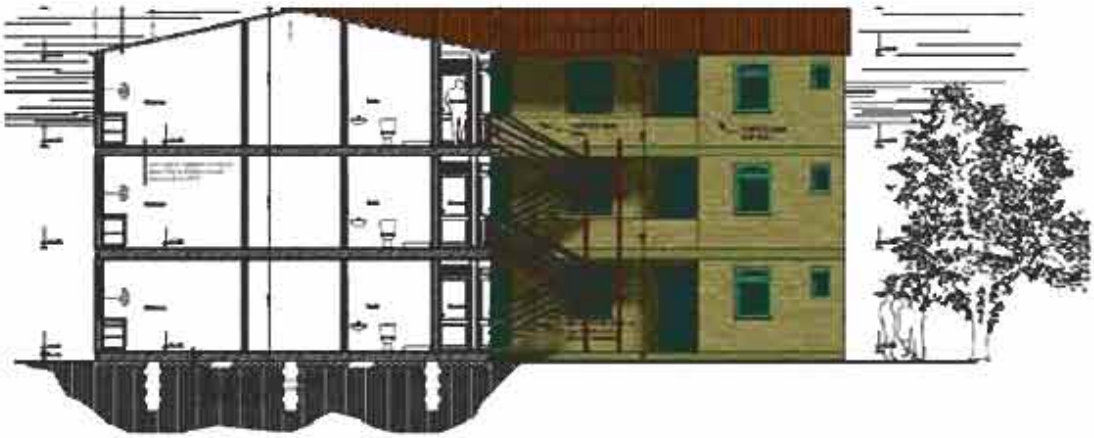
- Municipality (-ies)
- Respective Ministries
- Construction Sector Associations
- Utilities
- Banks
- GTZ
- Donors



Typical floor plan

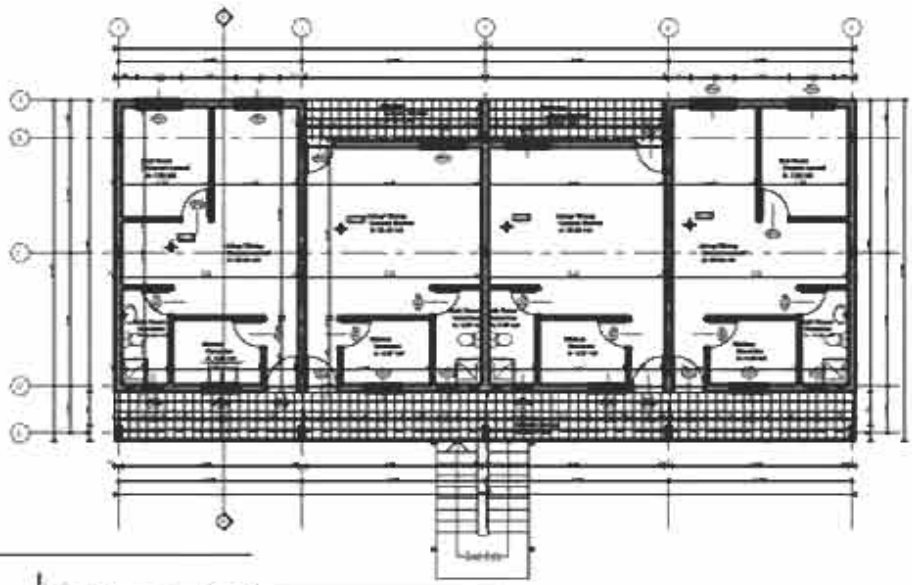
Back side elevation

Some implemented housing types from different sites: Lideta, Kirkos, Addis Ketema, Gulelle, Yeka, Mekanissa

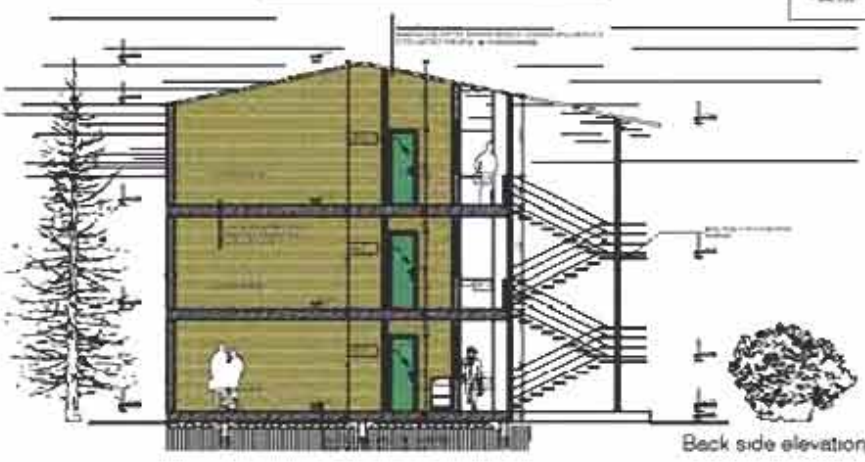


Section A-A

Back side elevation



Typical floor plan

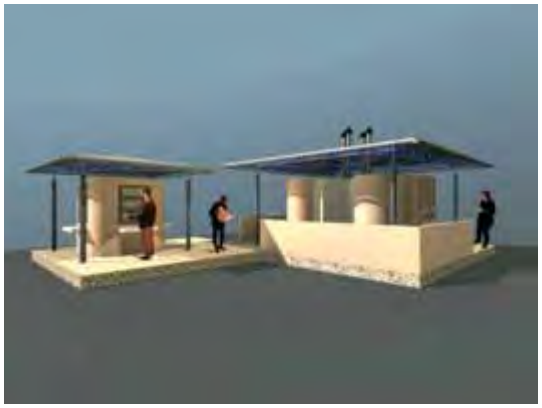


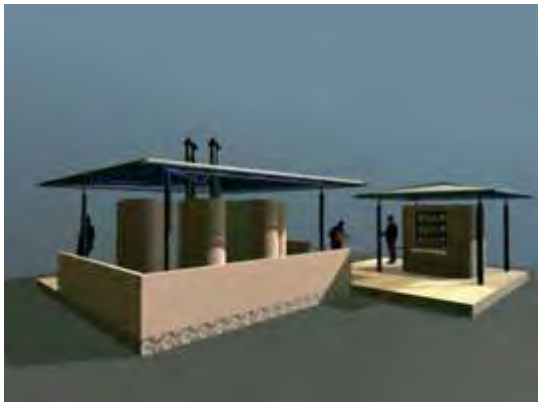
Back side elevation

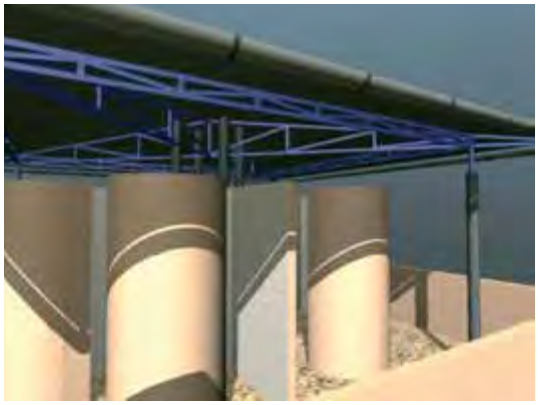
Some implemented housing types from different sites: Lideta, Kirkos, Addis Ketema, Gulelle, Yeka, Mekanissa

Gate House Type (design)

U-K Type (design)







Kiosk and public toilets (design)

Housing Type A, G+2 (design)

1. System approach

The LCH -MH Technology is to be conceived as a system (system approach) based on:

- Diversification/specialization/professionalisation of the construction sector,
- Specialization of subcontractors,
- Prefabricated elements and Cost-efficient management system.
- Fabricated construction elements (Hollow Concrete Blocks, U-shape Blocks, Slab Blocks, Precast beams and Precast Lintels),
- Construction material producers as well as,
- Qualified contractors and sub contractors,
- Trained, semi- and skilled construction workers.

The technology is modular and simple. Although it requires proper planning and care, it does not require highly skilled carpenters or masons. The technology is well suited to functions that are modular and repetitive like housing units (row houses, apartments, growing houses/ starter unit, class rooms, dormitories, office buildings, etc.).

Training - on - the - job as well as micro & small enterprise promotion is part of the integrated, labour intensive and employment generating approach. In order not to compromise the quality and the stability of the buildings only the structure of the buildings is done by bigger subcontractors. They (contractors for structural works) are required so that a reliable 10-year warranty is obtained which is required for structural works.

2. Problems

The Ethiopian construction sector is not yet ready for massive construction programs. There is a shortage of:

This holds true in particular if they are supposed to use the LCH-MH Technology. The problem becomes worse if the sites are outside of Addis Ababa, making supervision and quality control and the provision of building materials - at least in part - more difficult.

In order to apply the LCH-MH Technology, consultants as well as contractors are trained.

3. Diversification/ specialization/ professionalisation of the construction sector

GTZ IS works as Implementing (development) Agency with different subcontractors (for structure, for sanitary installation, for electrical installation). This has as consequence mutual control. Each subcontractor checks the other.

However, this system is new to Ethiopia and faces two problems:

1) Specialized subcontractors still have to be developed.
2) Warranty, as practised with general contractors, does not function any more in a system of multi specializa-

tion of contractors. According to the existing Ethiopian Laws, the responsibility/warranty falls back onto the Client.

4. Areas of training for specialization/ professionalisation

Areas of specialization in order to professionalize the construction sector and improve its quality are:

- scaffolding,
- metal formwork, also on a rental basis,
- electrical installation,
- sanitary installation,
- pre-fabricated construction materials,
- bar bending,
- ceramic tile laying,
- flooring,
- plastering,
- painting,
- road maker.

Moreover, construction site management is an essential area, which requires theoretical as well as practical training.

5. Road maker

Road making with natural stone in abundance available in Ethiopia is a new program of the Addis Ababa City Government. All pedestrian and internal roads will be paved with natural stone in the near future. Natural stone pavement has several advantages such as:

- Labour intensive,
- No sophisticated equipment required,
- Natural stone in abundance available,
- Low maintenance and repair costs,
- High aesthetical value.

Paving of complex stone patterns

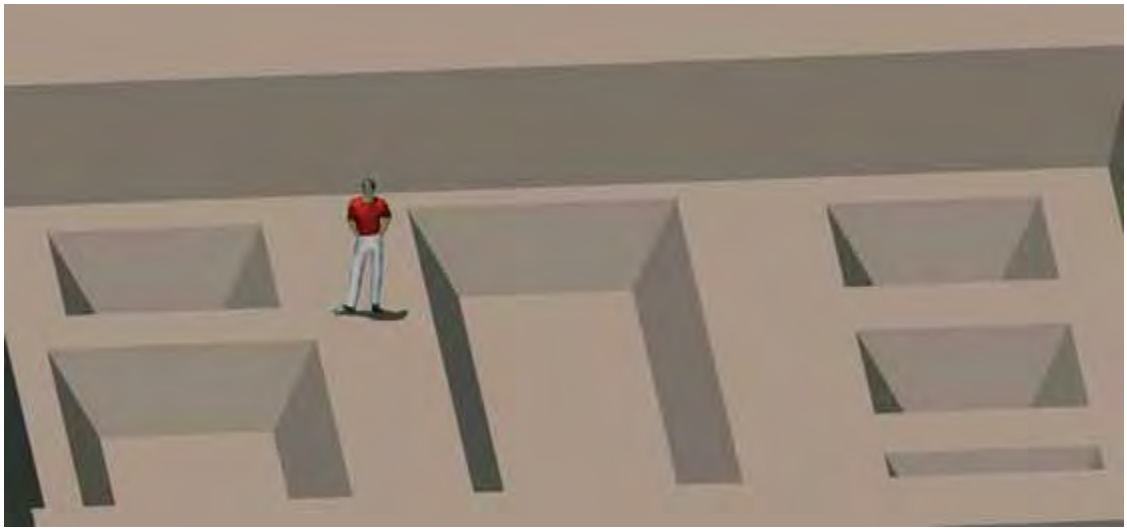
Cracking stones

Provision of hand hewn stones for the pavement

Stonework for Bole Gerji site

Paving procedure

Flushing of gaps



Excavation for foundation with terraces

Excavation & Earthwork

After the top soil is removed and the dimensions of the foundations are set out the excavation work for foundations can start.

- The structural drawings have to be checked carefully
  - width of excavation
  - depth of excavation
  - types of excavated materials
  - type of soil at foundation level.
- If the foundation is deeper than 1m it is recommended to build terraces were the workers can stand on to reach the bottom of the foundation without problems (see picture).
- The angle of slope depends on the soil and the weather conditions.
- Terraces and the right angel of slope will prevent that loose material can fall to the bottom of the foundation.
- The foundation pits and trenches must be free of groundwater and roots.
- If the excavated material can not be used as back fill material it should be cart away immediatly.
- Excavated material which will be used as backfill material should not be stored beside the excavation pits or trenches.

Lean Concrete

The lean concrete must be levelled precisely (waterlevel) and kept clean from all organical materials.

Reinforcement & Formwork (Footings)

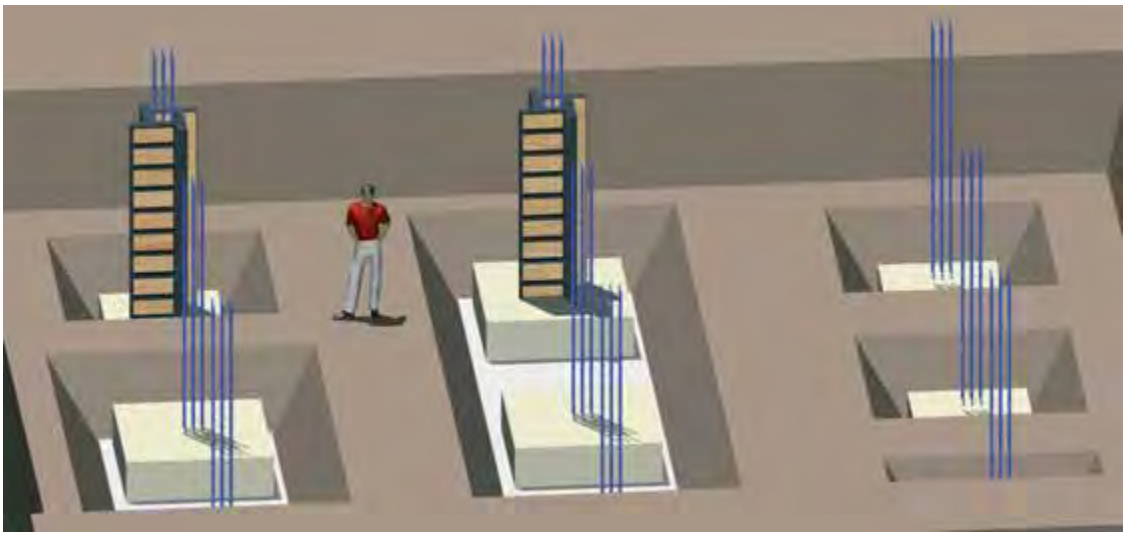
The most important parts of the building are the foundations.

All structural drawings must be studied carefully, and should be understood in all written and drawn parts. If this is not the case, the structural or resident engineer should give explanations !!!!

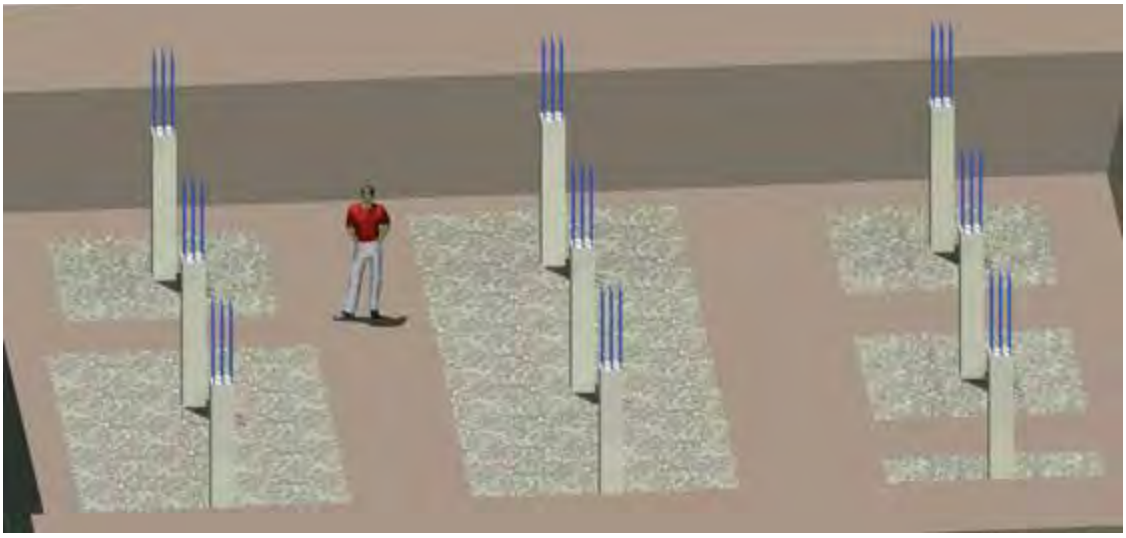
The foundation work should be checked according to the following list:

- Is the quality of the reinforcement bars proofed ?

- Is their quality according to the structural design ?
- Are all reinforcement bars installed accordingly to the structural drawings?
- Are the right bar diameters installed?
- Are the spacers in between the reinforcement and the lean concrete installed?
- Have the spacers the right dimensions (height)?
- Are enough spacers installed (middel and outside parts)?
- Are additional stirrups on top of the re-bars installed so that the re-bars cannot bend during the concrete work?
- Is the formwork for the footings well installed (height and width)?
- Are enough supports for the formwork installed?
- Is the bottom clean and free from organical material?
- Is the lean concrete watered (cured)?
- Are the test cubes prepared for concrete checking?



Footings, lean concrete and clumn formwork



Foundation with footing columns and backfill up to terrace level

Before starting the concrete work for the footings, a written approval from the resident engineer must be given.

Concrete work

The required strength of the concrete should be given in the structural drawings. The mixing rate for the required strength varies according to different conditions. There is no general mixing rate. The rate and the water-cement ratio depends on:

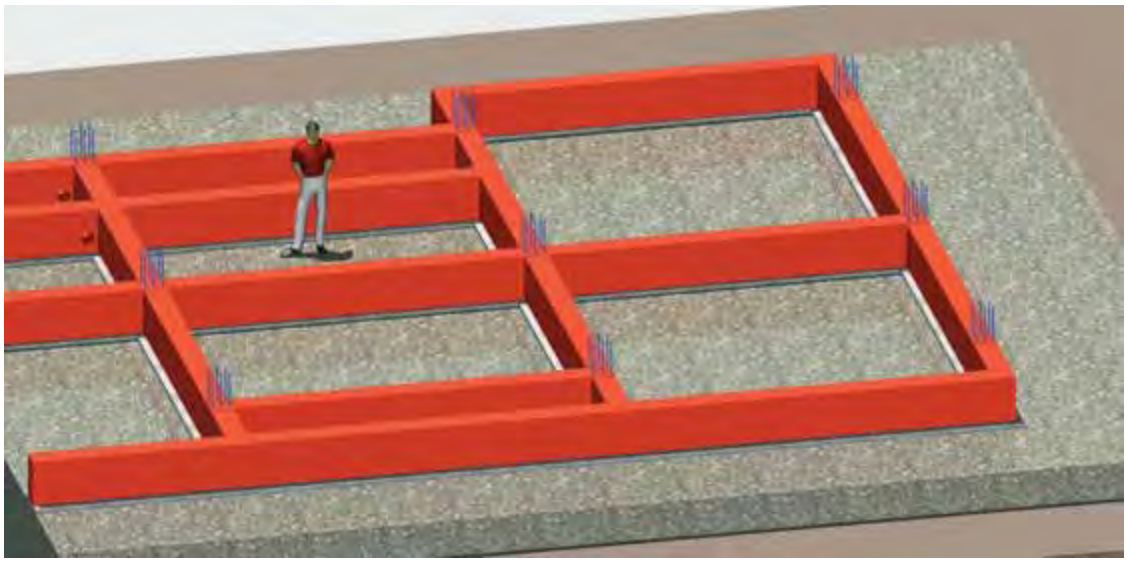
- weather conditions (sunny and hot - rainy and cold),
- dry aggregates / wet aggregates
- sizes of aggregates,
- condition of sand (washed, silty, dry, etc.),
- type of cement.

It is recommended to prepare test cubes with different mixing rates which have to be tested in an official laboratory in order to find out the right mixing rate under local conditions.

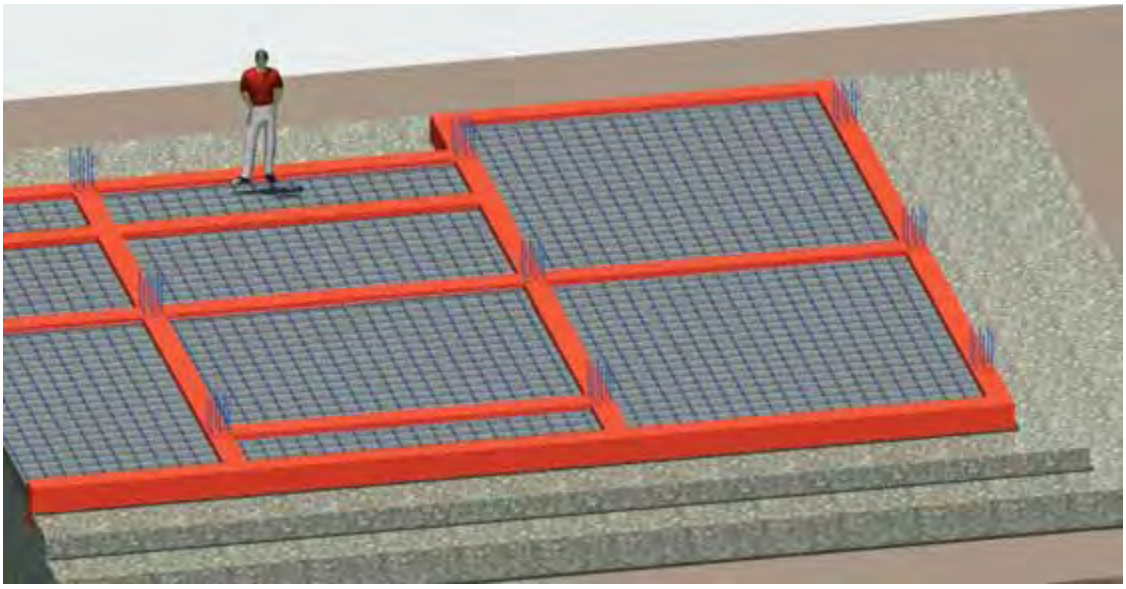
Footing columns

The construction of the footing columns should be checked according to the following list:

- Spacers should not be higher than the upper level of the concrete!!!!
- Is the future height of the concrete (filling height) levelled and visibly marked at the formwork?
- If the filling height of the concrete is more than 1.5 m , the aggregates will be separated during the filling!
- Is the formwork for the footing columns well installed (height and width)?
- The formwork should not be higher than 20 cm of the finished concrete level!!!!
- Are enough supports for the formwork installed?
- Is the bottom (footing) clean and free from organical material?
- Are all reinforcement bars installed accordingly to the structural drawings?



Lean concrete and grade beams



Grade beams with backfill, hardcore, temperature reinforcement without expansion joints

- Are the right bar diameters installed?
- Are the spacers in between the reinforcement and the formwork installed?
- Have the spacers the right dimensions (distance between bars and formwork min.= 2.5 cm)?

Before starting the concrete work for the footing columns, a written approval from the resident engineer must be given.

Backfill of excavated area around footing columns

Before starting the back fill work the resident engineer must approve the materials (selected material) for the back fill work.

In order to get a regulary compressive strength of the back fill, the steps of back fill should be marked at the columns every 20 cm. This means 20 cm of filling material (selected material), compaction and another 20 cm of filling material till the excavated hole is filled and compacted. The heights for compaction should be marked at the footing columns in order to control the right compaction.

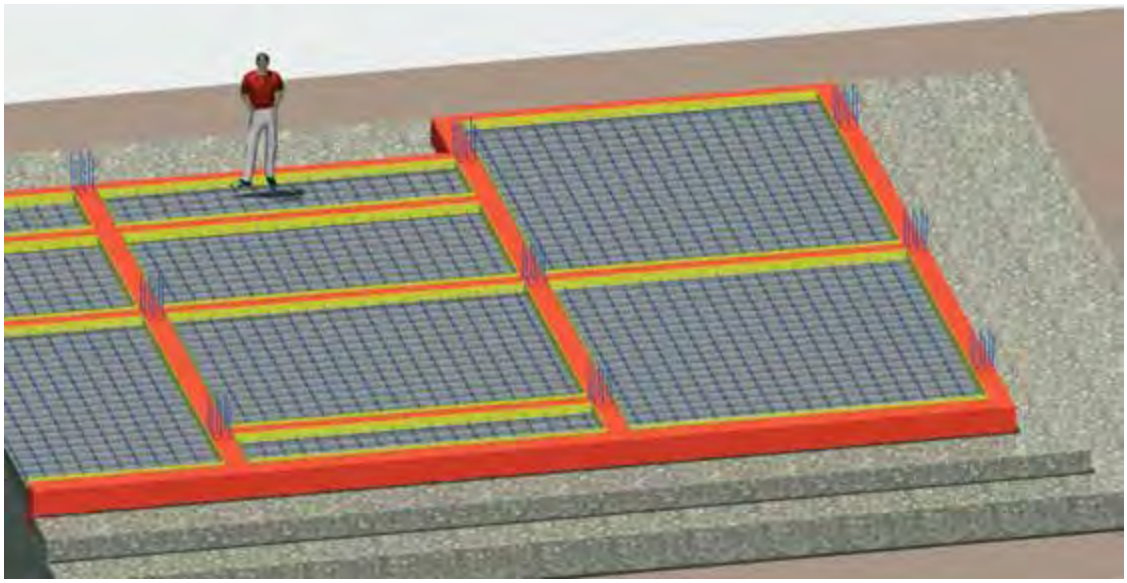
When the excavated holes are filled and compacted the whole area for the construction of the grade beams has to be backfilled and compacted (roller). This backfill has to be levelled (theodolite) in order to get the required height and a smooth surface for the lean concrete under the grade beams.

Grade Beams

After the backfill is well compacted and levelled, the lean concrete for the grade beams can be placed.

It is important, that the lean concrete is levelled because it will give the right height in between the spacers and the re-bars of the grade beam.

Also the formwork of the grade beam will stay on the lean concrete. Every difference in height of the lean concrete will



Grade beams with backfill, hardcore, temperature reinforcement with expansion joints

have consequences (level differences) for the formwork and later for the grade beam.

The construction of the grade beam should be checked according to the following list:

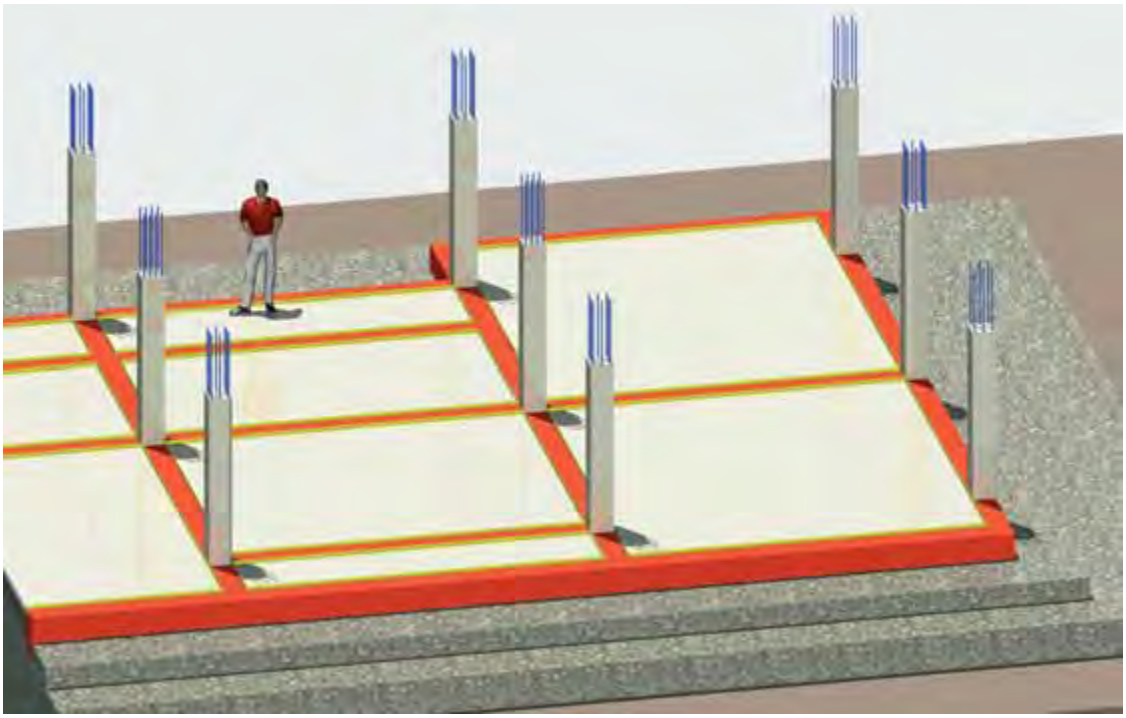
- Is the quality of the reinforcement bars proofed?
- Is their quality according to the structural design?
- Are all reinforcement bars installed accordingly to the structural drawings?
- Are the right bar diameters installed?
- Are the spacers in between the reinforcement and the lean concrete installed?
- Have the spacers the right dimensions (height)?
- Are enough spacers installed (middle and outside parts)?
- Is the formwork for the grade beams well installed (height and width)?
- Is the formwork straight and levelled?
- Are enough supports for the formwork installed?
- Is the bottom clean and free from organical material?
- Is the lean concrete watered (cured)?
- Are the test cubes prepared for concrete checking?

Before starting the concrete work for the footings, a written approval from the resident engineer must be given.

Sanitary installation

The sanitary installation (waste water line) has to be installed at this time. If the waste water line goes below the grade beam the pipes should be installed before the lean concrete is in situ.

The best solution is that the waste water pipes cross the grade beam in the middle. In the formwork for the grade beam an opening has to be prepared so that the waste water pipes can pass through. The



Grade beams with groundfloor concrete, expansion joints and columns up to first floor

openings must be bigger than the pipes in order to avoid any contact with the grade beam e.g. when the waste water pipe has a diameter of 110 mm the opening should have a diameter of 160 mm.
As the waste water line has a slope of 2%, the opening in the grade beam should follow this slope.

Backfill between Grade Beams

After the deinstallation of the formwork for the grade beams the backfill of the areas in between the grade beams can start.
The same procedure as with the backfill of the footings should be followed.

Hardcore & Lean Concrete

The hardcore consists of broken basaltic stones. The structural or resident engineer can change the specification to trachidic stones.
The hardcore has to be levelled so that it's height is equal on all parts.
On top of the hardcore lean concrete (C 5) has to be placed and levelled. The lean concrete avoids that the concrete on top (C 25) enters into the spaces between the hardcore.
It is very important that the lean concrete is levelled in order to get later on the right distance (equal distance) in between the spacers and the temperature reinforcement.

Expansion joints

In between the grade beams and the floor concrete expansion joints have to be provided. The floor concrete does not have any direct contact to the grade beams. Fore the expansion joint styro foam of min. 0.5 cm should be used. Organic material like chipwood is not

recommendable, because it will expand when it gets wet.

Floor Reinforcement

When the expansion joints (styro foam) are fixed the reinforcement bars for the floor can be installed. The exact positions are shown in the structural design. It is important that enough spacers are installed and the height of the spacers is kept accordingly to the design.

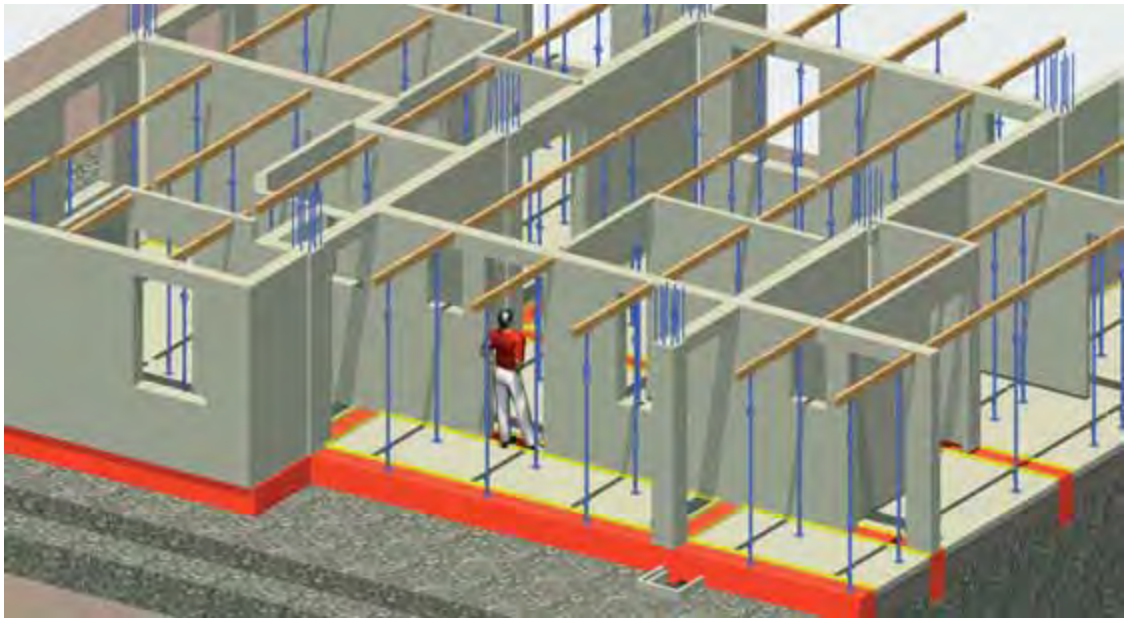
Under normal soil conditions the spacer will have a minimum height of 2.5 cm while in black cotton soil the reinforcement is 2.5 cm below the floor finishing level.

Columns

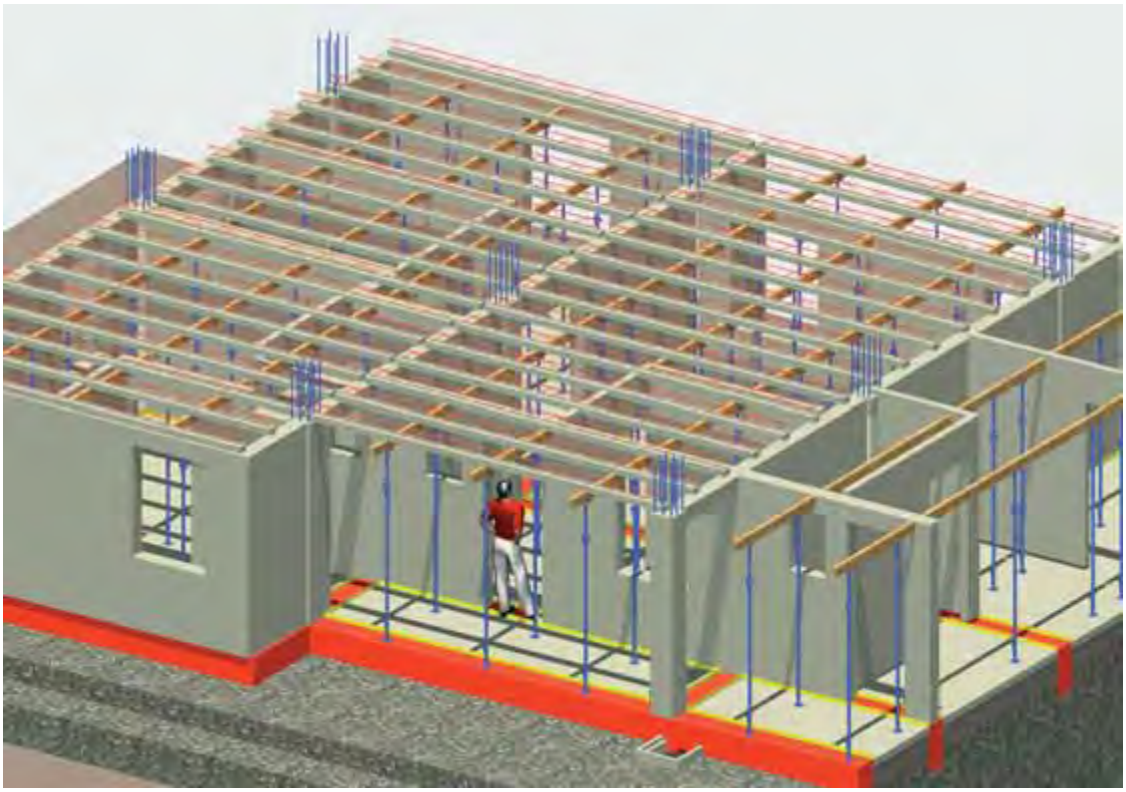
Before starting the erection (construction) of the columns, the structural design has to be studied carefully in order to avoid future construction problems. Especially the position of the re-bars is very important because the pre-cast beams sometimes are laying on top of the columns. If the re-bars are not in the right position the pre-cast beam will not fit in between the re-bars.

The column work should be checked according to the following list:

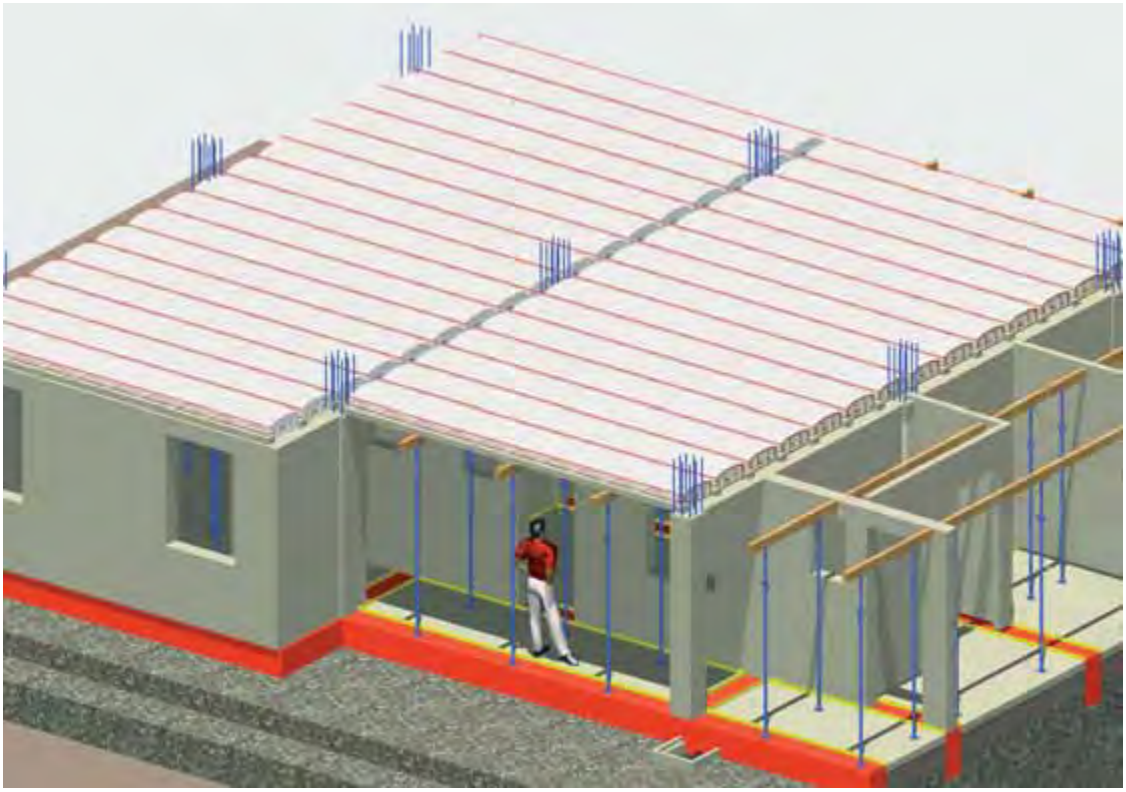
- Are all reinforcement bars installed accordingly to the structural drawings?
- Are the right bar diameters installed?
- Are the spacers in between the reinforcement and the formwork installed?
- Do the spacers have the right dimensions (distance between bars and formwork min.= 2.5 cm)?
- Spacers should not be higher than the upper level of the concrete!!!!
- Is the future height of the concrete (filling height) levelled and visibly marked on the formwork?
- If the filling height of the concrete is



Temporary support for prec-cast beams (slab construction)



Installation of pre-cast beams



Pre-cast beams and slab-hollow blocks installed

more than 1.5 m, the aggregates will be separated during the filling!
- Is the formwork for the footing columns well installed (height and width)?
- The formwork should not be higher than 20 cm of the finished concrete level!!!!
- Are enough supports for the formwork installed?
- Is the bottom (footing) clean and free from organical material?

Before starting the concrete work for the footing columns, a written approval from the resident engineer must be given.

Block Work (Wall construction)

Before starting with the block work all measurements (level of grade beam, floor height, columns, etc.) have to be controlled.

The height of the first layer has to be given to the masons and marked at the columns.

It is advisable to measure and mark at the columns all other layers in order to give a guideline to the masons.

The wall construction should be checked according to the following list:

- Is the mix proportion of the mortar given?
- Is the mortar well mixed?
- Is the strength of the hollow blocks controlled??
- Are the HCB's well stored beside the construction area to avoid longer transportation ways?
- Is the working place for the masons prepared?
- Do the masons have enough hand tools to erect a straight, upright wall?
- Are the corner angels correct (90 degrees)?
- Is the wall straight and upright?
- Are the conduits for the electrical installation installed accordingly to the electrical design?

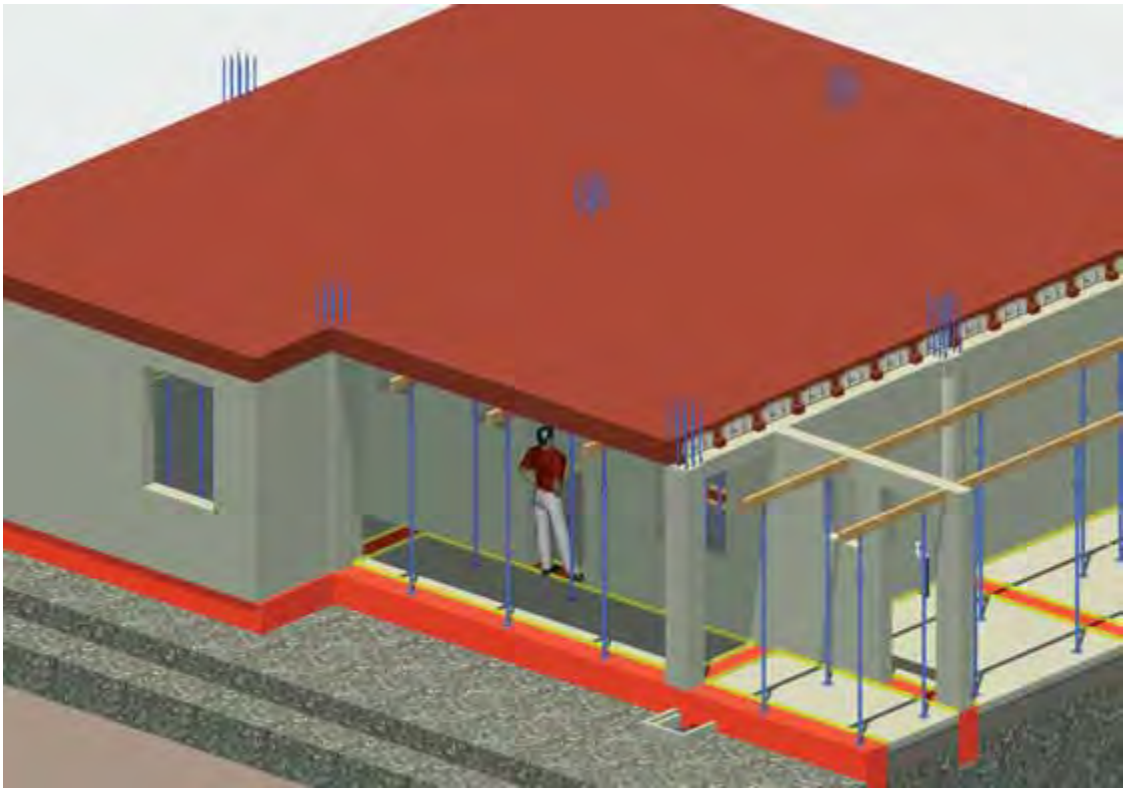
Especially the U-blocks for the ringbeam must be absolutely straight levelled because on top of the ring beam the pre-cast beams will be layed. If there is any level difference, the slab will not be straight and the pre-cast beams will be bented.

Slab Construction

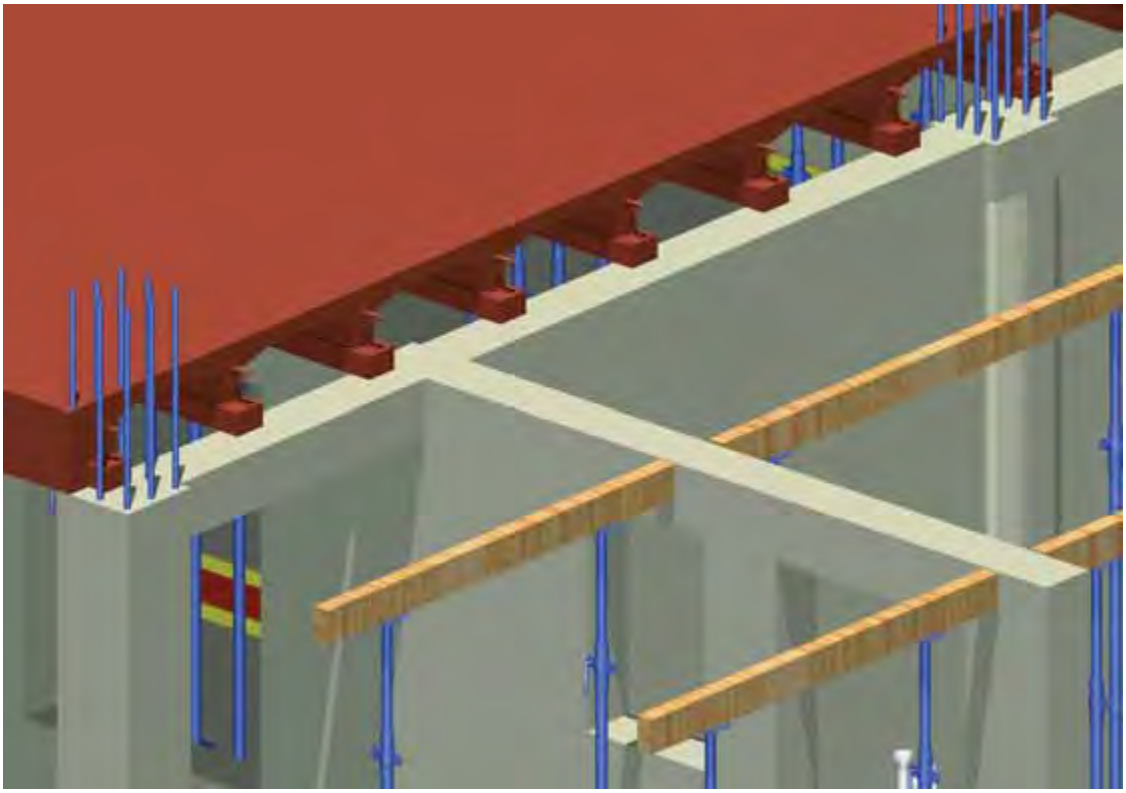
The slab construction starts with the installation of the slab support. Three supports have to be installed, one in the middle of the slab and two on both sides of the slab 1 m in front of the walls. The support line should be given in the structural drawings. The pre-cast beams should lay on a squared timber (sawn timber). Eucalyptus poles are not the adequate material for the horizontal support because they are not straight enough and hence can be bented. Every deflexion of the pre-cast beams should be avoided.

Before the beams are laid on top of the support, they should be checked. Especially the part where the slab hollow block will be placed should be clean and straight.

The correct level of the beams should be controlled before the slab hollow blocks



The finished first floor slab



The load bearing part of the slab (without hollow blocks)

are placed.

The slab HCB´s, hanging between the precast beams are functioning like a (lost) formwork. They give only a temporary support during the installation phase. Only the pre-cast beams and the slab concrete (C 25) are load bearing parts of the slab. When all the HCB´s are laid, the electrical installation can be installed. After the electrical installation (conduits, etc.), the temperature reinforcement will be installed accordingly to the structural design. Spacers have to be installed in order to keep the reinforcement in the right position. It should be avoided, that too many people are walking on top of the ready installed slab before the concrete is casted.

All open spaces in between the hollow blocks have to be closed by mortar in order to avoid that the cement water is dropping down. If this happens, the load bearing capacity of the slab will be dramatically reduced.

The concrete work should only be started after the written approval of the resident engineer. He has to check if all installations are well done and all reinforcement bars are installed accordingly to the structural design.

Large scale storage of mineral aggregates

Large scale concrete mixer

The mixing unit with integrated weighing scale

Compared to on-site production, prefabrication has got a lot of advantages. Among these are:

- cost-effectiveness,
- higher quality,
- higher reliability of quality,
- improved quality control,
- easier implementation of quality standards.

Big amounts of stored mineral aggregates with the same grain size provide large numbers of building parts with the same quality. The production process is supervised and the product can be checked for its quality.

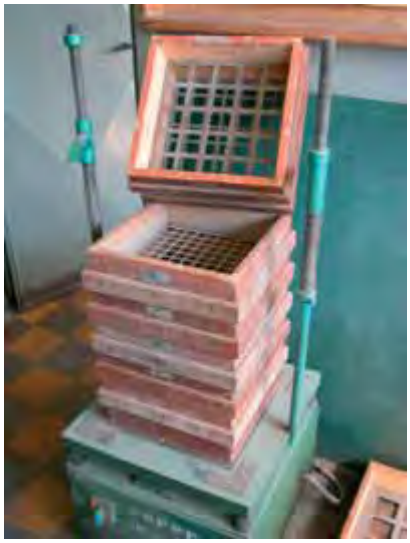
Screens and weighing scales are used to ensure the correct grain sizes of the aggregates and the correct grading curve.

To find out the right mixture for mineral aggregates, cement and water, testing cubes are casted in different mixing ratios. After proper curing these concrete cubes are tested for their maximum compressive load with a testing press. Doing this, the calculated mixing ratios can be checked in reality.

Weighing scales

Testing press

The mould with the reinforcement ready for casting



Screens for provision of the correct grading curve

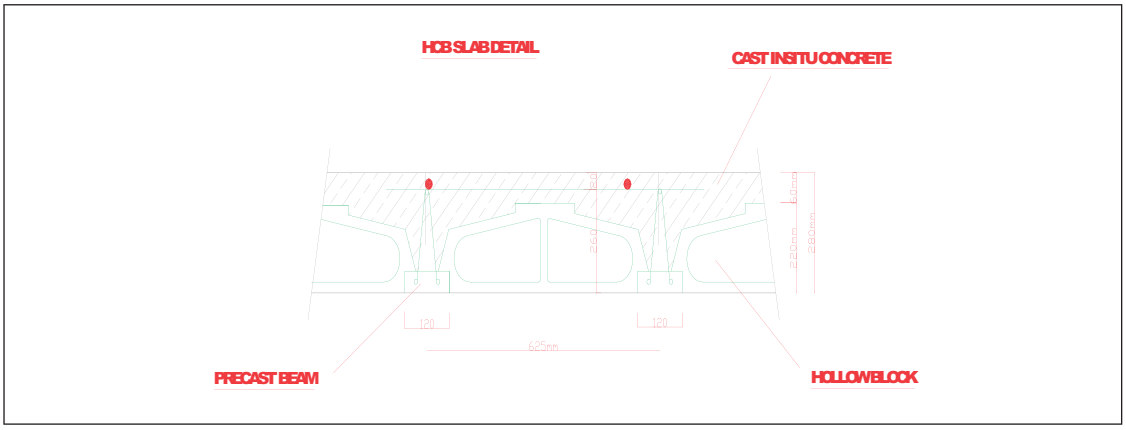
Stretching of reinforcement

Casting of concrete into the mould mounted on a vibrating table

Curing of testing blocks

Bending of reinforcement

The vibrating table

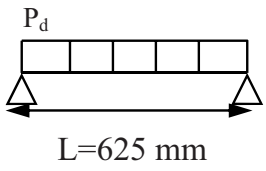


Analysis of slab

The slab is made of precast beam systems that are used together with hollow blocks. The precast beam is spaced at an interval of 625 mm.

TOPPING REINFORCEMENT

The topping is a one way slab that is supported on the precast beams.



Taking a one meter strip and analyzing the slab it could be shown that the area of steel to be provided is minimum. The shear should also be checked because of local shear developments due to small slab depth.

The maximum shear developed $v_{max} = p_d/2$ is checked against the capacity of the section and it is determined whether shear reinforcement should be provided or not. In the present example no shear reinforcement is provided since the applied shear is less than the capacity of the section. Minimum reinforcement from the code suggests that a reinforcement mesh providing in each direction a cross sectional area not less than .001 of the section of the slab should be provided.

A typical section of a slab with minimum reinforcement is shown in fig. 1.

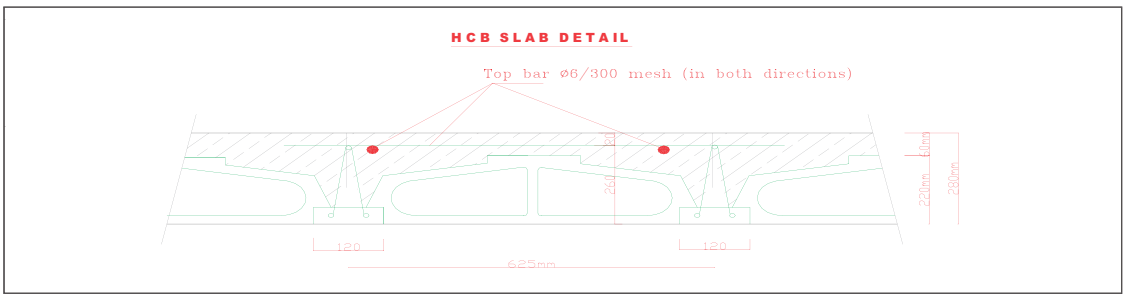


Fig. 1: section of slab at final condition

Analysis of precast beam

The analysis of the precast beam is divided into two parts:

1. Initial condition
2. Final condition

Initial condition

For smaller spans up to 4 m the precast beam has a concrete section of 60 mm depth and 120 mm width at initial condition. For larger spans up to 5 m a concrete section of 80 mm depth and 120 mm width has been used. For initial condition this precast beam is laid on the main beams supporting it. Since the initial condition is a transitory period the depth of the precast beam is chosen fulfilling the flexural requirement which is shown later. A typical precast beam section is shown in Fig. 2.

This precast beam is to be supported at midpoints in order to meet it's design requirements typical section of a precast beam with the hollow blocks at initial condition is shown in fig. 3.

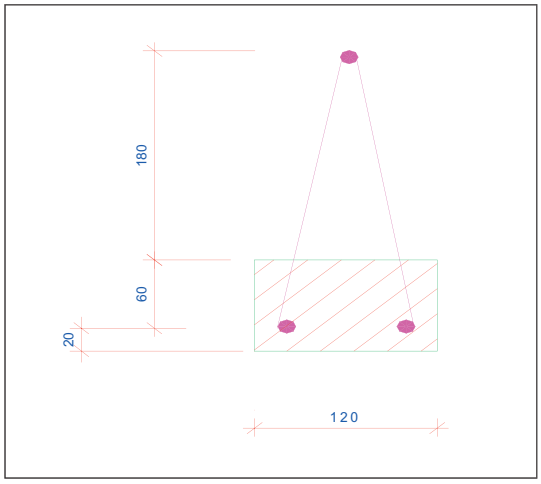


Fig. 2: Detail of precast beam

The precast beam at initial condition is designed to carry the live load and dead load. It is provided with shear reinforcement that is compared with the code requirements and the load that comes to it.

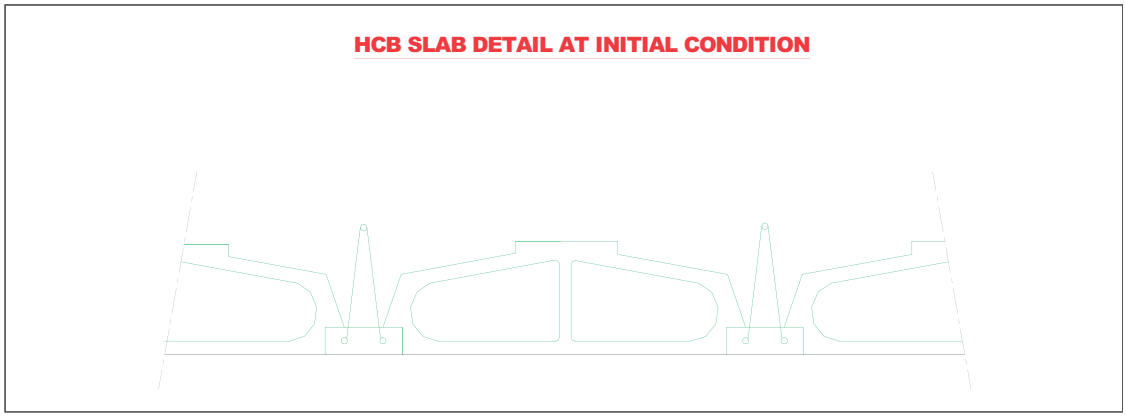


Fig. 3: Precast beam and HCB arrangement before top slab casting

Typical analysis of a precast beam at initial condition

LOADING:

dead load (g_k):

precast beam	:	1.3*.12*.08*25	=	x
concrete block	:	weight of hollow block	=	y
				Σg_k

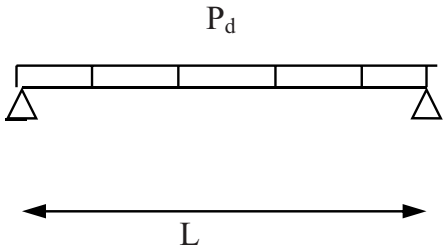
live load (q_k) :

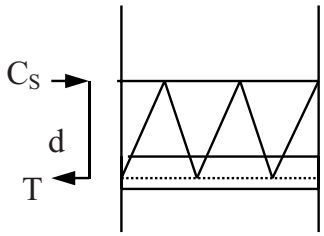
depends on the purpose of structure = q_k

design load :

p_d = $1.3g_k + 1.6q_k$

SYSTEM:

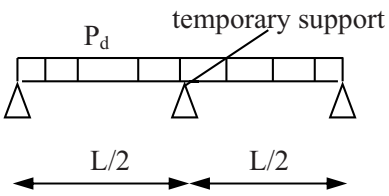




$$M_{max} = \frac{P_d * L^2}{8} \qquad c_s = \frac{m}{d}$$

The compressive force c_s should be multiplied with the buckling ratio of the reinforcement and it's divided with the area of the re-bar which is checked with the allowable stress. The bottom reinforcement should be able to carry the design moment.

In some cases where the span is longer the precast beam isn't able to carry the design moment and an intermediate support is provided and the analysis is done as shown before.



$$M^+ = \frac{9\ P_d * (L/2)^2}{128}$$

The corresponding c_s is calculated and it's divided with by the area of the reinforcement which is checked against the allowable stress capacity of the reinforcement. This is provided as a bottom reinforcement.

$$M^{-} = \frac{P_d (L/2)^2}{8}$$

This is the negative moment developed at the temporary support. In the same case the stress coming to the reinforcement should be less than the allowable stress.

Checking for shear

The shear force in the beam is calculated for maximum value. (v_{max})

v_{max} is distributed to the diagonal reinforcements and the appropriate re-bar is selected which can carry the induced stress.

Final condition

The section of the slab at final condition is shown in fig 4.

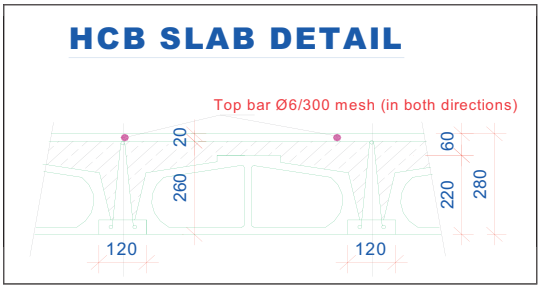


Fig. 4: Section of slab at final condition

Loading:

dead load (g_k) :

precast beam : 1.3*.12*.08*25	=	x
concrete block + cast insitu concrete	=	y
floor finish + partition	=	z
	Σ	g_k

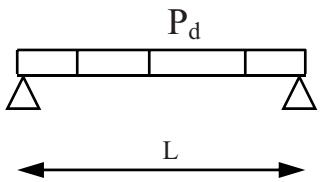
live load (q_k) :

depends on the purpose of structure

design load:

$p_d = 1.3 * g_k + 1.6 * q_k$

SYSTEM:



The depth D varies depending on the span.

A depth of 280 mm was used for apartments with 5.0 m span in Addis Ababa

$m_{max} = P_d * L^2$

$$d = \frac{8}{D\text{-}d'\text{-cover}}$$

$$\mu_{us} = \frac{m_d}{f_{cd} * b * d^2}$$

for this value of μ_{us} a graph is read from EBCS code and the value of k_x is read.

$k_x = x/d$

From this we can get the value of x.

This value is checked against the centroidal axis of the beam and it determines weather the beam acts as a T-beam or a rectangular section.

The same graph is used to determine the value of k_z.

$A_S = M/K_Z * d * f_{yd}$

The above equation is used to determine the area of steel.

CHECK FOR SHEAR

The shear force that comes to the structure equals

$v_{sd} = p_d * l/2$

This value is compared with the code requirements of the section which are:

1, $v_{sd} < v_c$

2, $2/3 v_{RD} < v_{sd} < v_c$

3, $v_{sd} > 2/3\ V_{RD}$

Then the appropriate shear force equation is used to determine the reinforcement to be provided. All equations are checked against the requirements of the code.

The longitudinal section of a typical precast beam is shown in fig. 5.

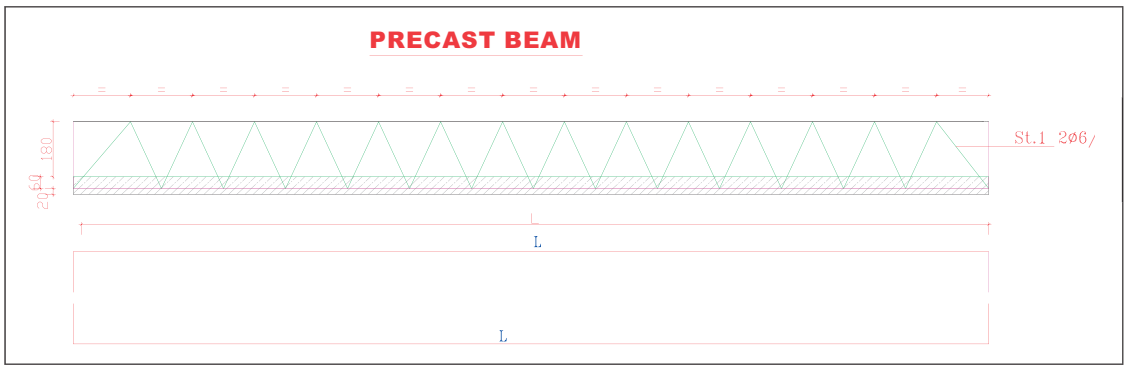


Fig. 5: typical longitudinal section of precast beam

Analysis of beam and columns

The beam is the primary structure that supports the precast beams.

There are two types of beams used in this approach:

- Beam in U shaped HCB (supported by the wall)
- Beam without wall support

Beam in U shaped HCB

As it is mentioned above the beam carries load that comes from the precast beam and wall above and transfer it to the wall under and to the columns.

Given a masonry stiffening wall that is constructed into the frame it can be expected that due to the restraints of the frame to the stiffening wall, the wall will act as a diagonal within the frame and significantly reduce the loads imposed on it. The function of the stiffener wall is only limited by the shear capability . Tension forces will be mainly eliminated by the frame vertical members if the mortar joint b/n the horizontal frame member & the wall provides sufficient contact. But due to imperfect construction of the wall & also quality of hollow blocks it will be difficult to assume that the wall will totally carry & transfer the load from precast beam & the wall above. And therefore in designing the girder beams , the wall is assumed to carry only some percentage of the vertical load.

Additional horizontal reinforcement within the hollow block may be considered to upgrade the wall shear load bearing capacity.

Beam without wall support

This beam is used when there is no wall support due to openings and cantilever positions, a small formwork is provided under this beam. The analysis of this beam and columns and the frame as a whole is made in a software using a 3-D model (SAP 2000 was used in this case).

The column is totally braced by the wall. To consider this effect the wall is modelled together with the frame element in the analysis.

A typical section of the U-beam supporting a precast beam is shown in fig. 6.
The layout of the precast beam is shown for a typical apartment.

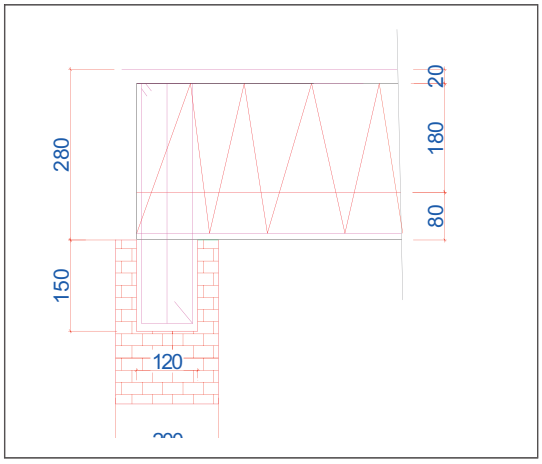
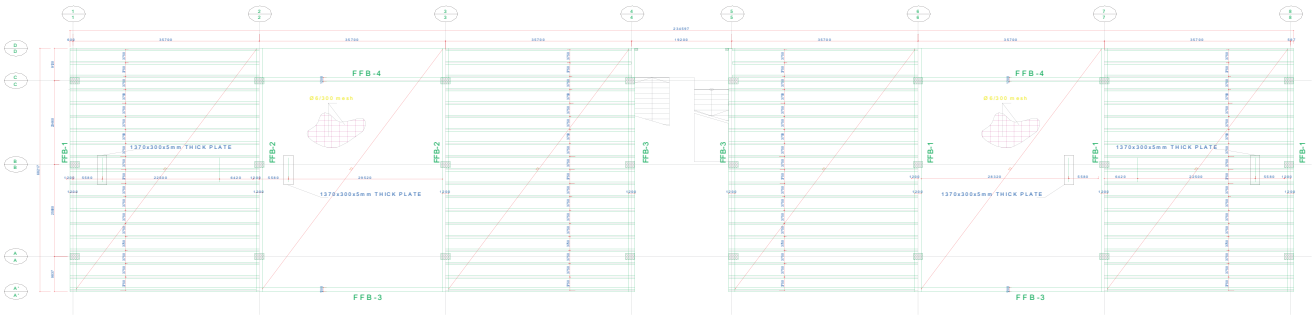


Fig. 6: typical connection detail of U beam and precast beam



The precast beams are connected with reinforcement that is wasted on site in order to take care of small negative moments that might develop and to insure stability. In the same way precast beams at the edges are provided with additional negative reinforcement to take care of cracks that might develop by a negative moment.
The additional re-bar is shown in fig. 7.

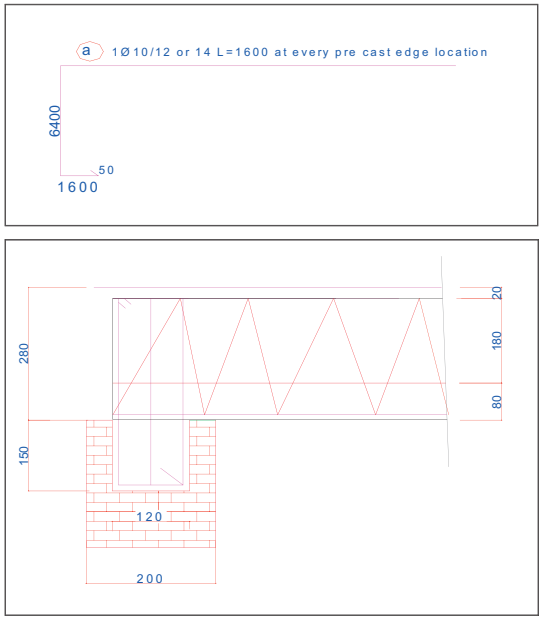
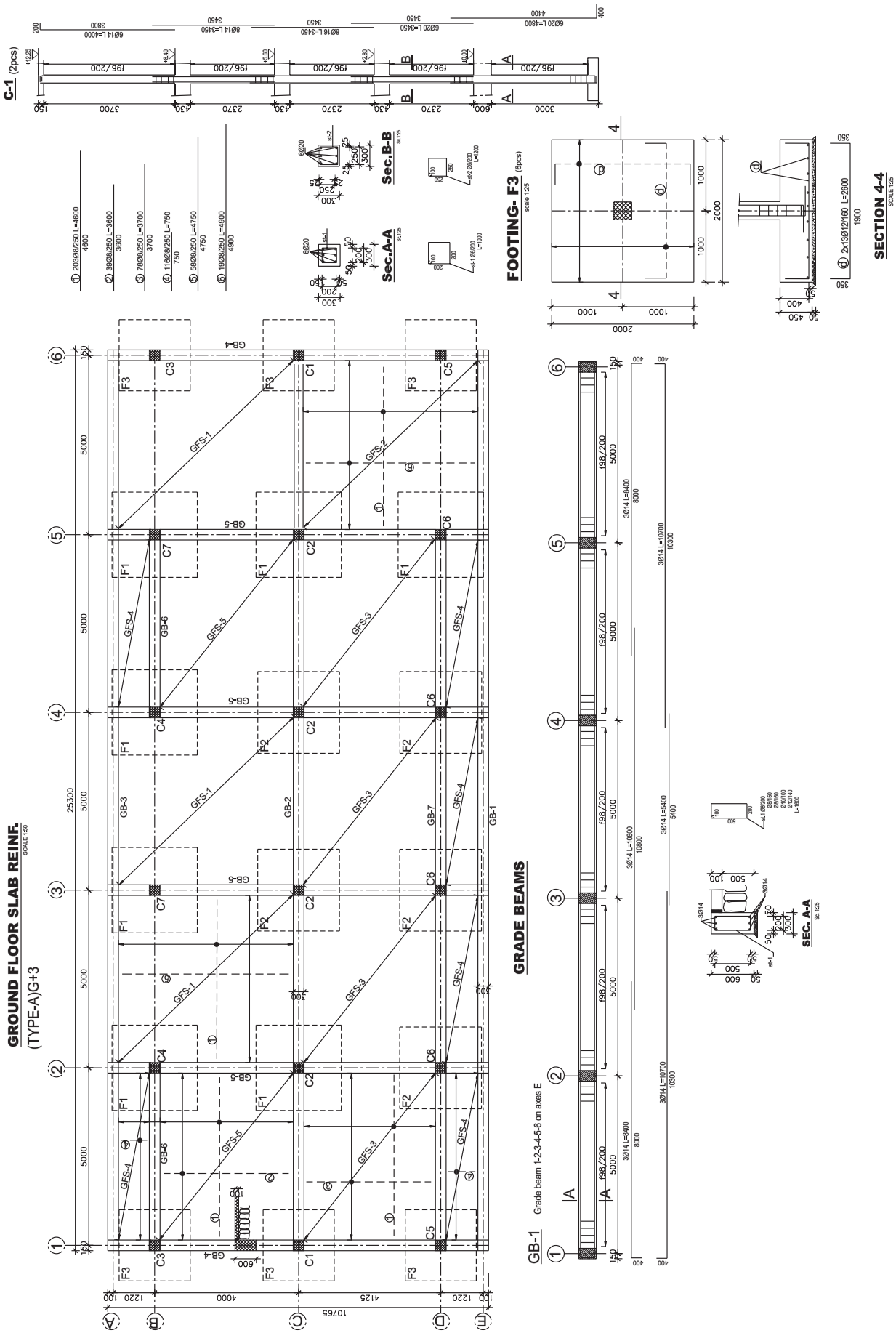


Fig. 7: Additional re-bar at edge

Usage of the hollow block wall as a structural element

The hollow block used in the construction of the low cost house is used in the analysis as a load bearing wall. It is assumed to have 20% of modulus of elasticity of concrete.

The 3-D model of an apartment building using the wall as a structural element is shown below.

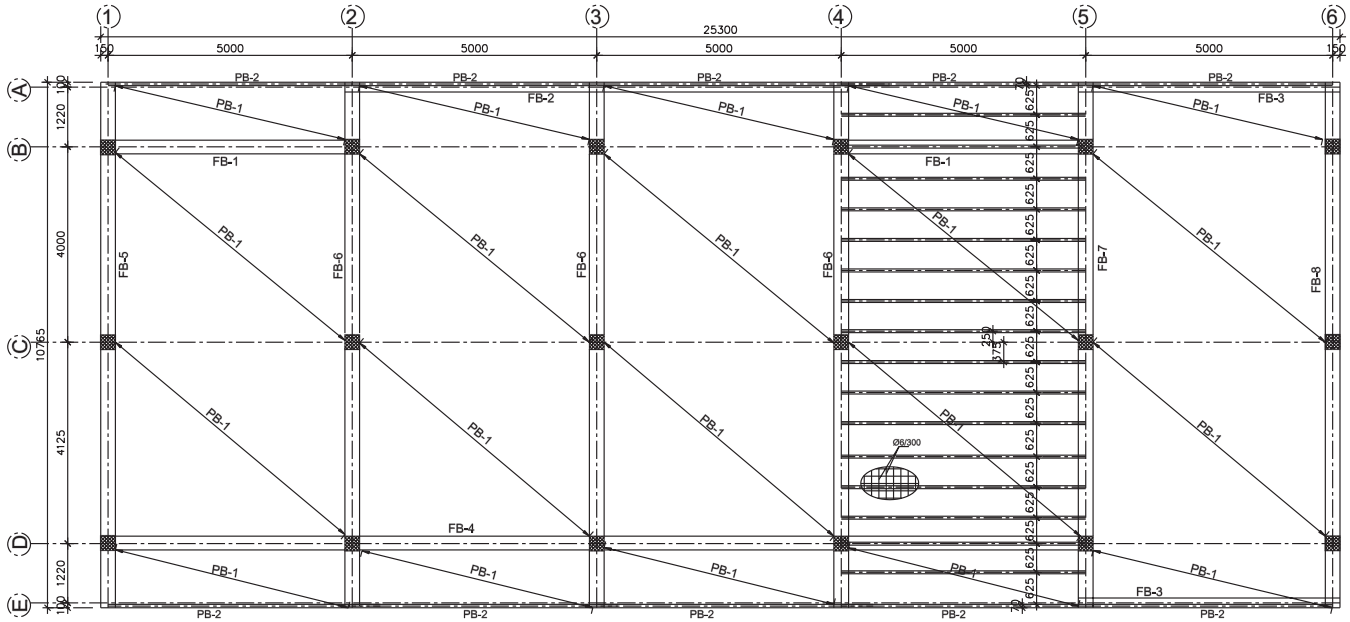


Typical structural drawings for apartment buildings

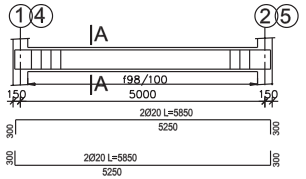
FIRST,SECOND & THIRD FLOOR SLAB REINF.

(TYPE-A)

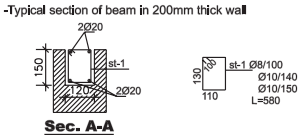
SCALE 1:50



FB-1 Floor beam 1-2/4-5 on axis B

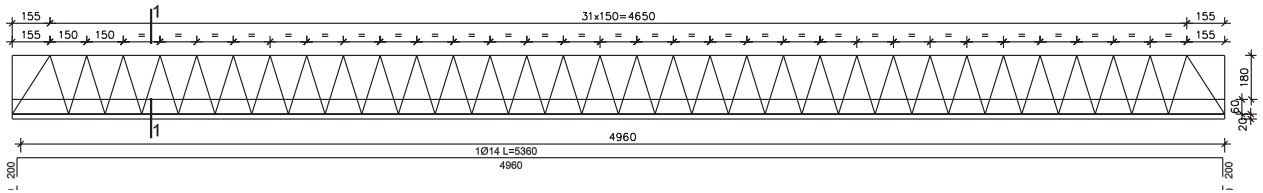


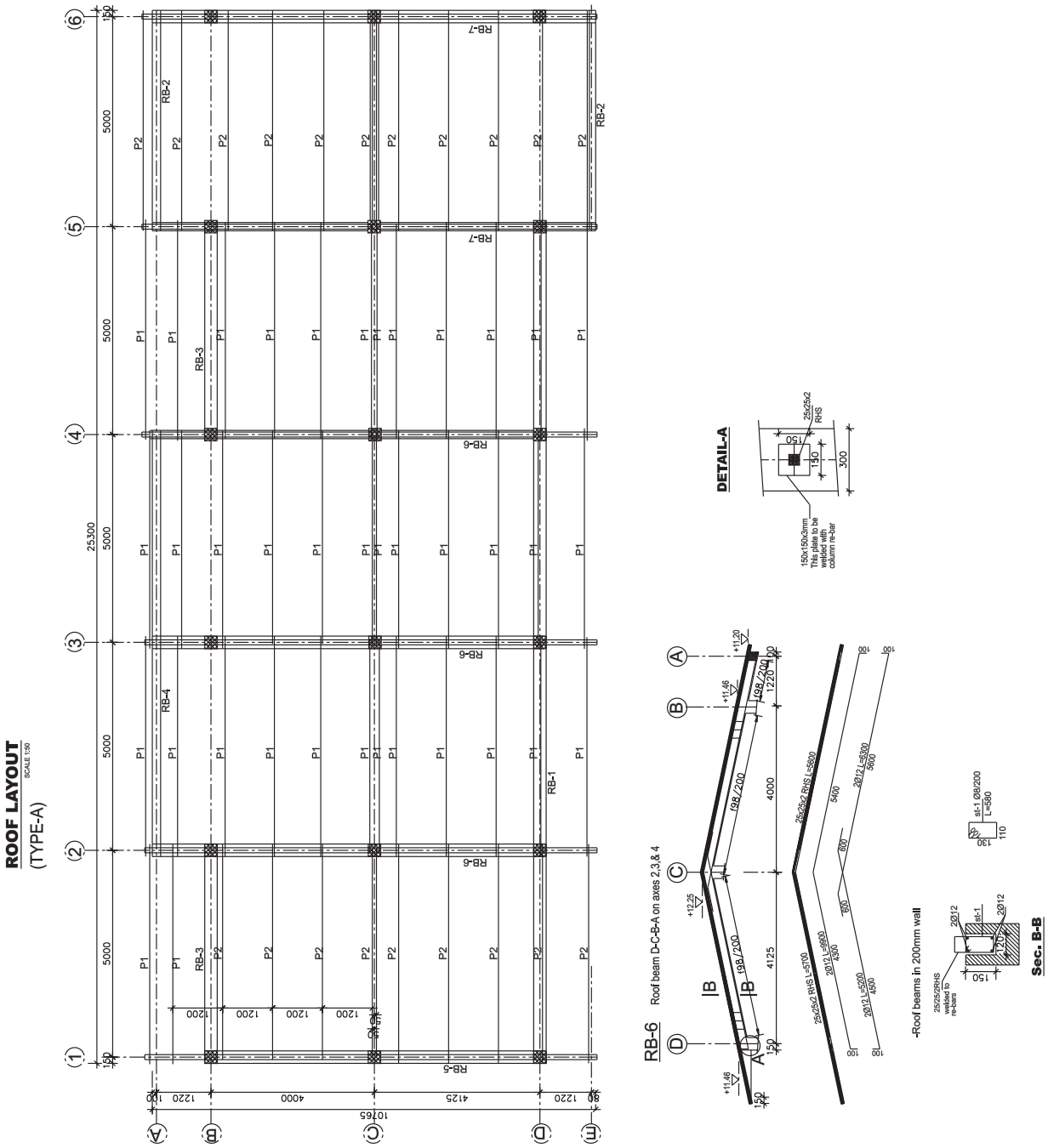
-Typical section of beam in 200mm thick wall



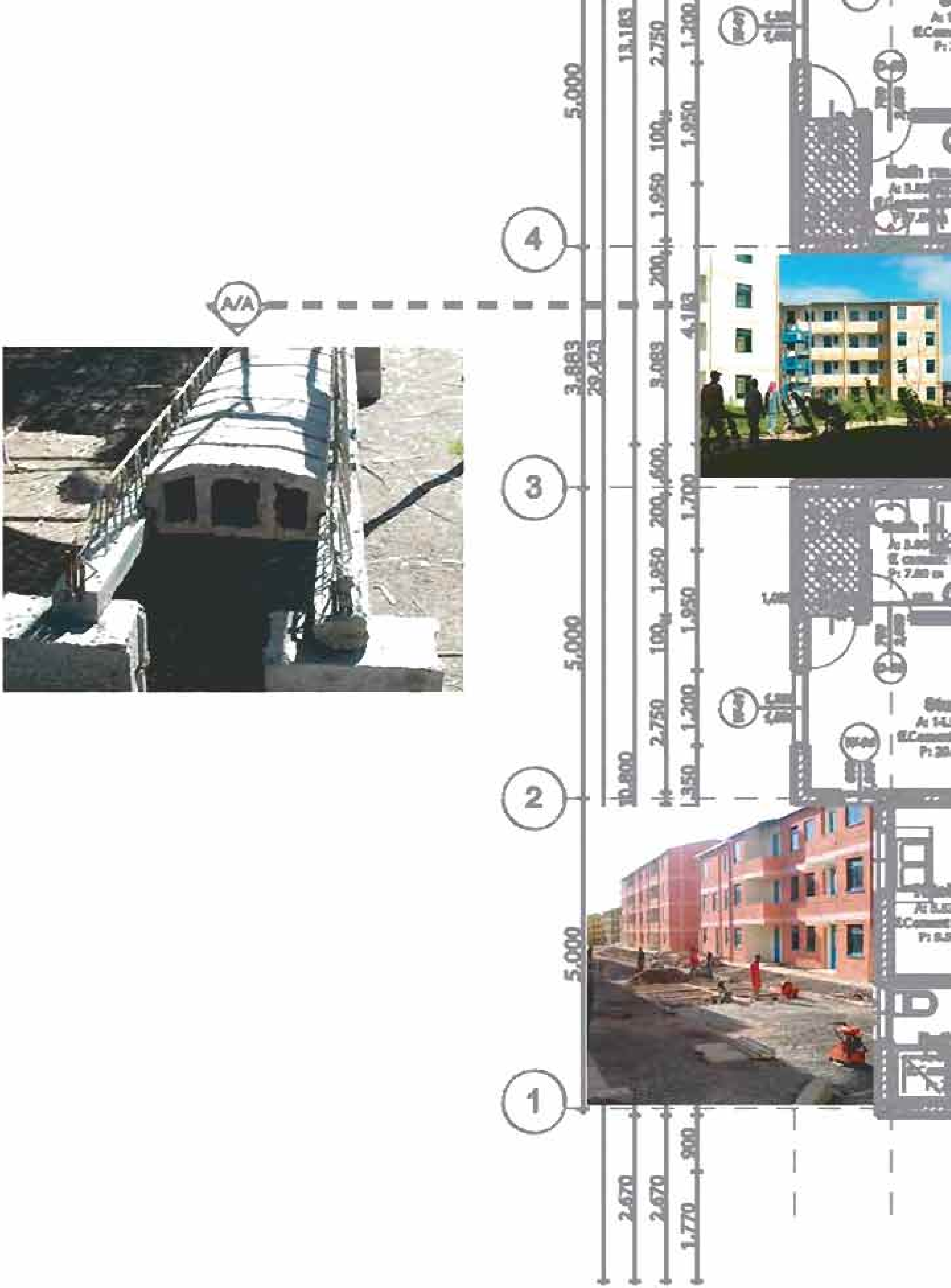
PRECAST BEAM -1 (240pcs)

Sc. 1:10





Typical structural drawings for apartment buildings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