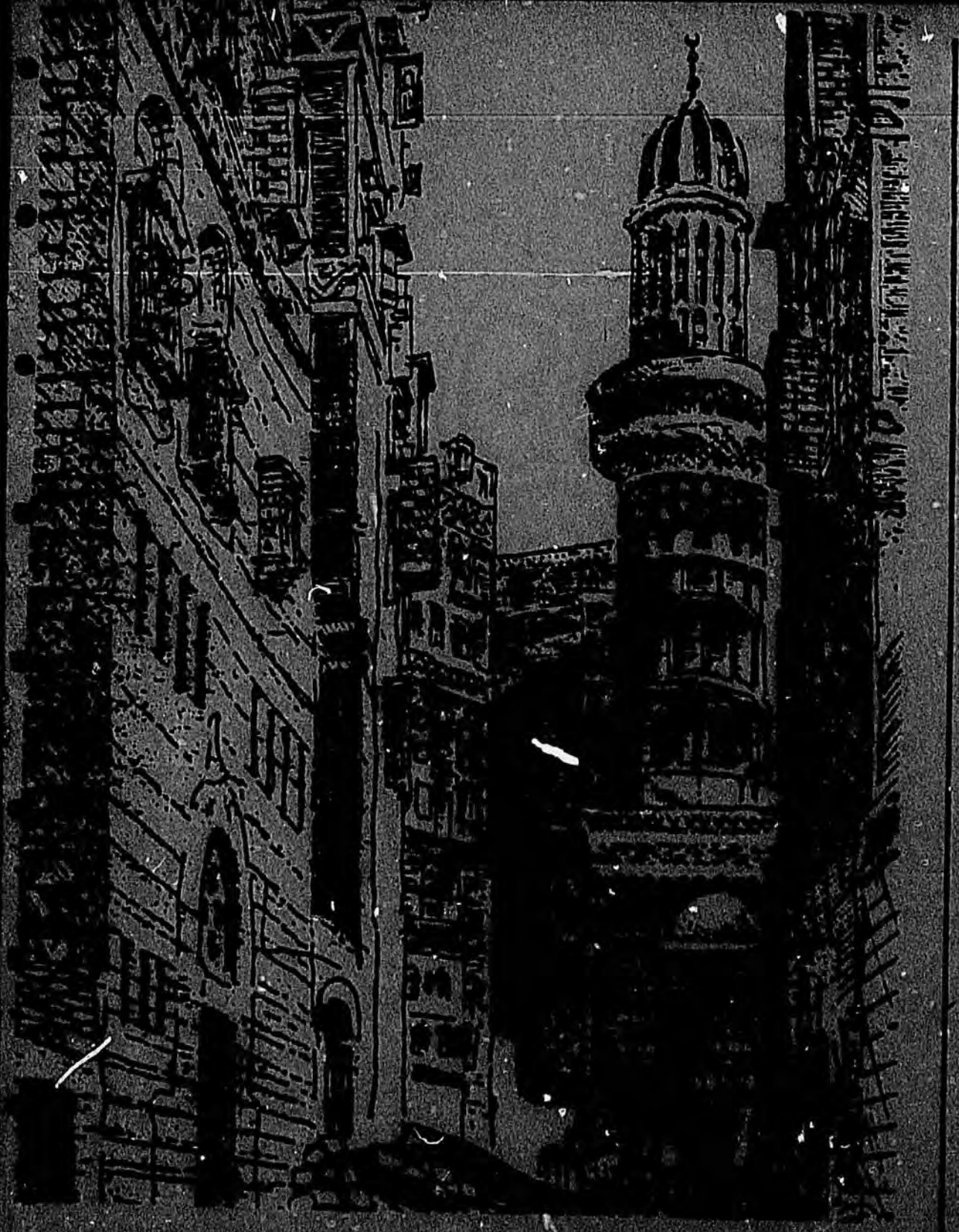

PROJECT DEVELOPMENT AND SUPPORT
EARTHQUAKE REHABILITATION - CONSTRUCTION
PROJECT NO. 298-0035

UNITED STATES OF AMERICA
AGENCY FOR INTERNATIONAL DEVELOPMENT

AGUIRRE ASSOCIATES
ARCHITECTURE · PLANNING · ENGINEERING

PROJECT DEVELOPMENT AND SUPPORT

EARTHQUAKE REHABILITATION - CONSTRUCTION

PROJECT No. 298-0035

PREPARED FOR

THE SUPREME COUNCIL FOR RECONSTRUCTION

OF EARTHQUAKE AFFECTED AREAS IN THE

YEMEN ARAB REPUBLIC

JOHN AGUIRRE, A.I.A., ARCHITECT - PLANNER

AGUIRRE ASSOCIATES, INC., RANCHO PALOS VERDES, CA

UNITED STATES OF AMERICA

AGENCY FOR INTERNATIONAL DEVELOPMENT

SANA'A, YEMEN

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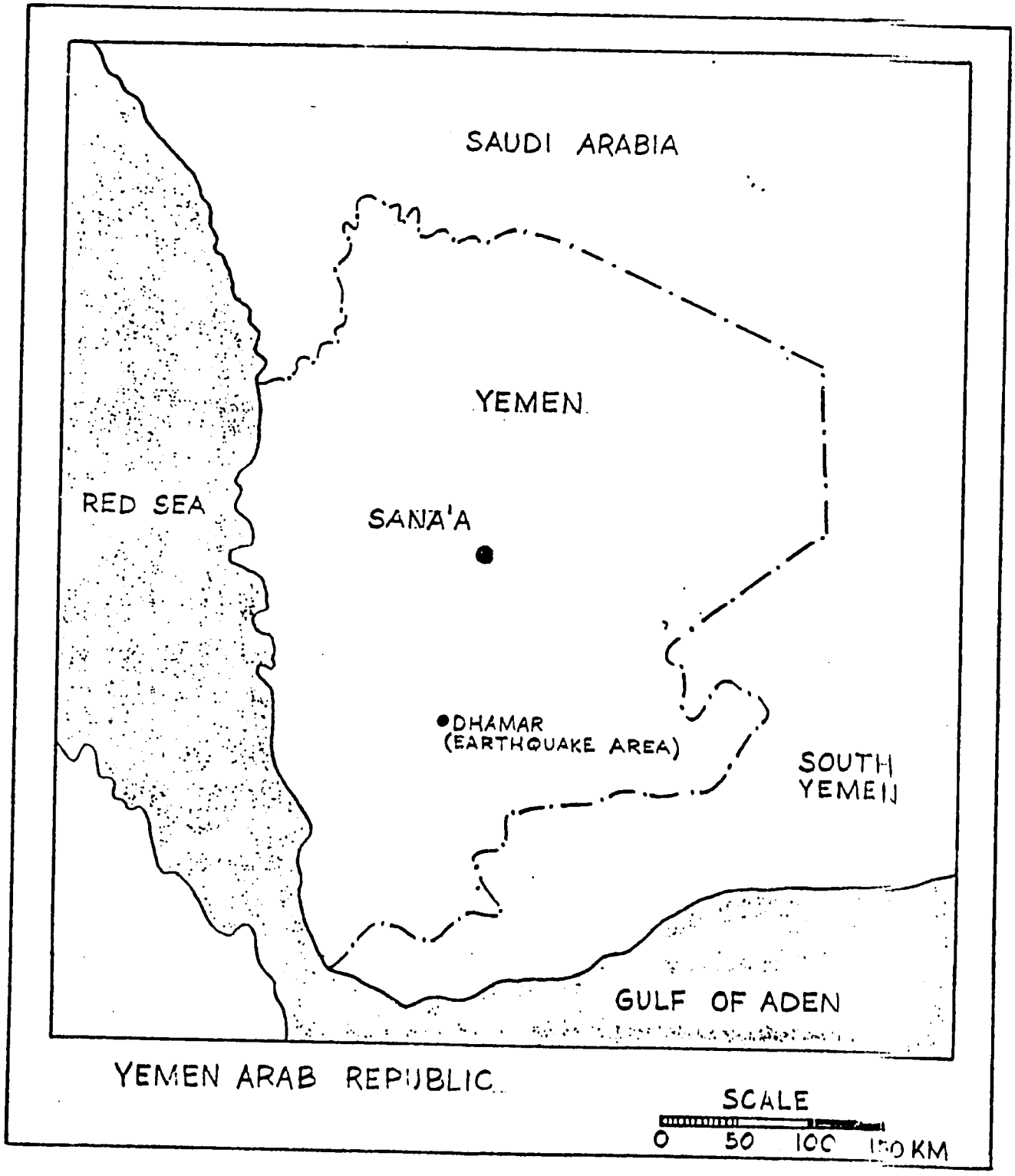

SAUDI ARABIA
YEMEN
RED SEA
SANA'A
DHAMAR
(EARTHQUAKE AREA)
SOUTH
YEMEN
GULF OF ADEN
YEMEN ARAB REPUBLIC
SCALE
0 50 100 150 KM

FORWARD

1. On December 13, 1982, an earthquake of major intensity struck the Dhamar Province, in the Yemen Arab Republic, (YAR). The shock, with an intensity of 5.8 on the Richter Scale, was followed by a second major earthquake on December 30th. The effect of the two earthquakes was to devastate the Province, damaging over 42,000 houses. Sixteen hundred people were killed and fourteen hundred were injured by the earthquake.

2. Almost all of the damage was limited to residential buildings. A few schools and mosques were also damaged. As the area is rural, there was very little damage to public services. Government estimates of the damage list 15,000 houses as totally destroyed, 14,000 houses as being re-usable after a structural examination and minor repairing to make them safe. The government estimates that 13,000 houses will require major repairs or possible demolishment.

3. As a result of the earthquake, the YAR established the Supreme Council for Reconstruction of Earthquake Affected Areas, (SCR). The Supreme Council is under the personal direction of the Vice-President of the Republic, H. E. Mr. Abdul Aziz Abulghani. The SCR has been assigned broad powers in planning, engineering and construction management in order to house the displaced population in the Dhamar Province.

4. The Government of YAR started its reconstruction program with the establishment of the SCR. At this time the SCR has completed a structural survey of a few thousand of the damaged houses. It has completed the design of a proposed model home and some model village plans. The SCR estimates that it will need around YR 2.8 billion, (U.S. $260 million), to complete the reconstruction program. The YAR has budgeted YR 1.75 billion of its own funds and is attempting to secure the remainder from foreign sources according to the World Bank report.

5. The United States of America, Agency for International Development, (USAID), is participating in these preliminary programs with the assignment of American architects and engineers to advise in developing earthquake resistant structures and in assisting in the survey of the damaged buildings.

SUMMARY

1. The government of YAR has begun its reconstruction efforts with the establishment of the SCR. The distressed people in the Dhamar Province are receiving aid from both government of YAR agencies and foreign relief groups. In addition, they have received aid from the United States and neighborhing Arab countries.

2. With the approach of winter, the SCR feels it is essential that the people in the area should move out of the tents and metal sheds and into permanent housing. The SCR has started a survey of salvagable houses as the first step towards providing assistance.

3. Many of the villagers have already started their own reconstruction programs, replacing tumbled walls and roofs and have moved into their old homes. Others have started building new concrete block houses throughout the area.

4. USAID will be providing architects and engineers to begin the structural analyses of the damaged houses in the Dhamar Province. This proposed survey will provide SCR with an indexed list of houses that can be rehabilitated, houses that need moderate to major repairs and houses that should be demolished.

5. The USAID consultant has provided design information and recommendations for earthquake resistant buildings to the SCR.

6. The USAID consultant provided an evaluation of Yemeni building materials and building technology. He has suggested alternate construction systems and design methods to make the traditional Yemeni house earthquake resistant, using low-cost building materials and methods. The proposed designs utilize traditional design and the use of local skills.

7. The SCR has designed a model housing unit and a prototype village as the start of its reconstruction program.

8. The SCR has issued a Prequalification Questionnaire for the construction of 15,000 houses that is due the end of July.

I. PROJECT BACKGROUND

A. The USAID "Project Development and Support Earthquake Rehabilitation - Construction," was designed to provide technical assistance to the SCR at the primary level of design and planning. This project is based on the concept that the traditional Yemeni building systems using walls of sun-dried mud brick, unreinforced concrete block and loose stone rubble would not provide resistance against future earthquakes. The project mandate was to provide building safety within the framework of traditional Yemeni architecture.

B. A damage assessment team sponsored by USAID will start a house-by-house survey this summer. It is scheduled to take four months.

C. The SCR is under the personal supervision of H.E. Mr. Abdul Aziz Abdulghani, the vice president of the YAR, and functions under the State Minister's Office.

D. The SCR has started its efforts by designing a prototype model home and a prototype model village.

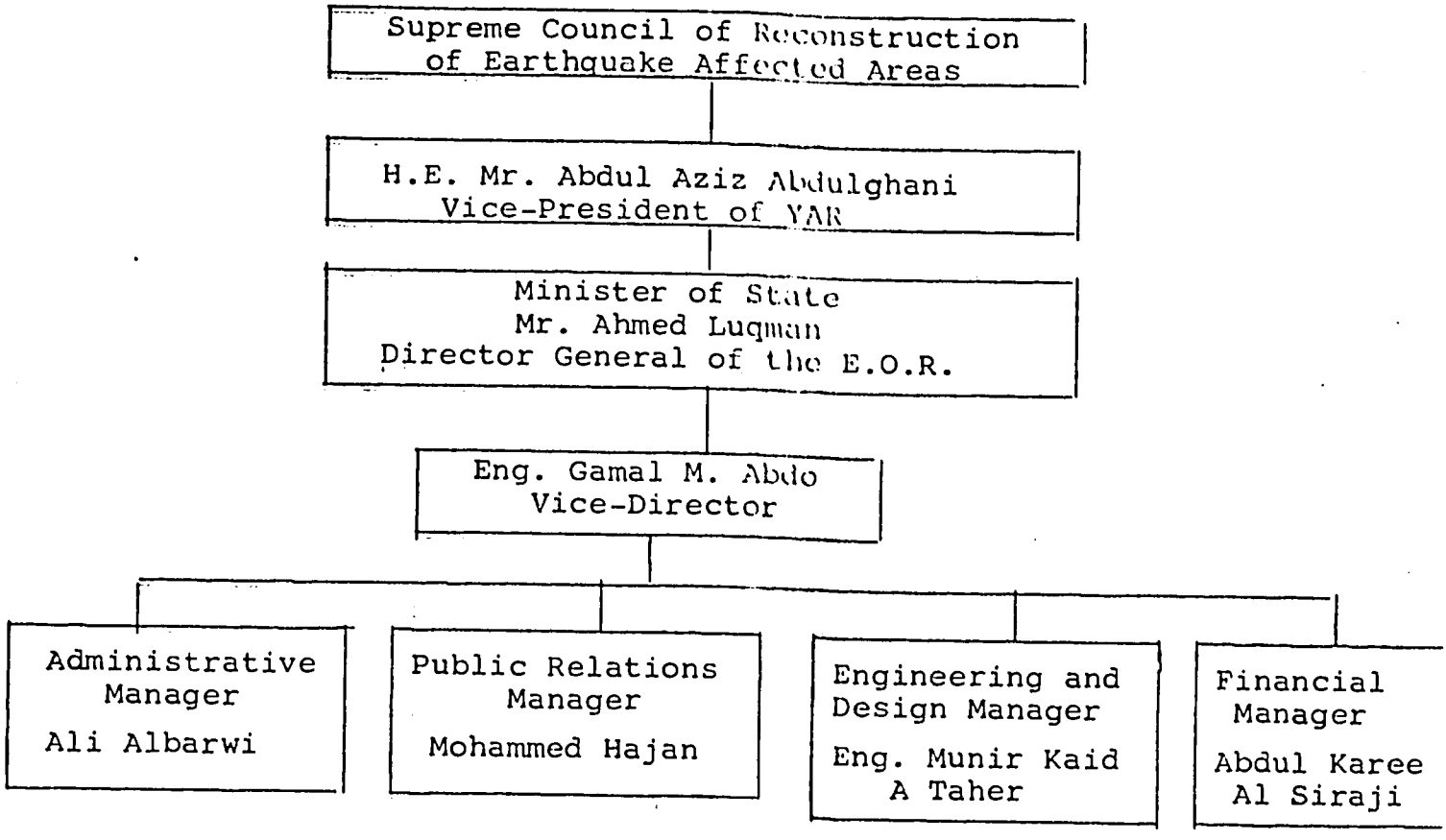
E. The firm of Aguirre Associates, Inc. of California was selecte by the USAID to provide design and engineering assistance to the SCR.

F. The SCR is planning to construct 15,000 new houses in the Dhamar Province as a replacement for 15,000 homes that were totally destroyed in the earthquake.

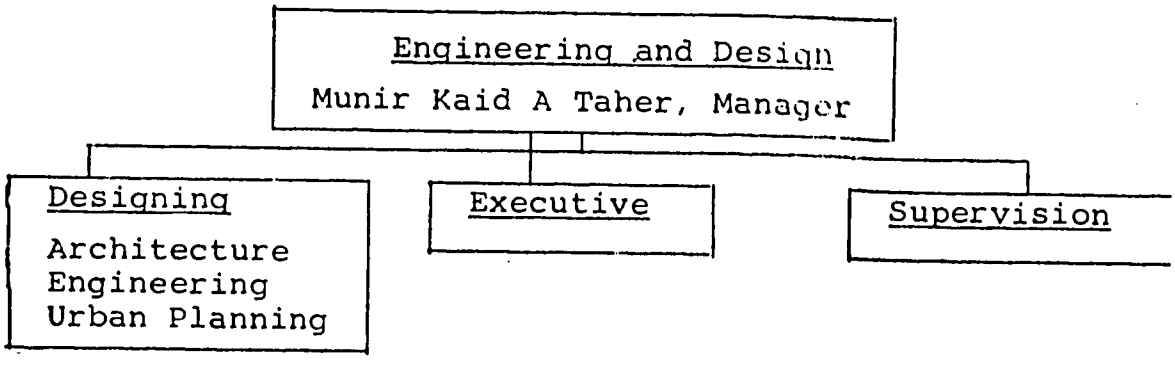
II. PLANNING AGENCIES

A. The Government of YAR has created the Supreme Council for Reconstruction of Earthquake Affected Areas (SCR) as

its design, planning and construction task force for the reconstruction of Dhamar Province.



B. The Engineering and Design department is responsible for all architectural, engineering and construction management services. It is organized as follows:



The staff, totaling 12, is composed of Yemeni and expatriate architects and engineers.

III. MODEL VILLAGE PROGRAM

A. The SCR has completed their design of the first prototype model village. The SCR is planning to build 120 villages as the first step of its Reconstruction Program. It eventually will construct a total of 1,200 villages by the end of the Program.

B. The model village is based on the hub concept. Each village has a town center as a hub, with residential satellite villages radiating from the hub. Each of the satellite villages will have approximately 40 houses.

C. The SCR is considering the use of Computer Aided Drafting Systems in order to meet its deadlines in producing the 1,200 designs.

IV. MODEL HOUSING UNIT

A. A prototype model housing unit has been designed by the SCR. The unit is 7.4 meters long and 6.0 meters wide, with a floor area of 44.4 square meters.

B. The house is constructed of concrete block walls, with a concrete slab floor and concrete flat-top slab roof. The roof is designed as a future second story floor. The house is supported by the traditional Yemeni post-and-beam system. The posts and columns are of reinforced concrete.

C. The SCR estimated cost of the unit is YR 50,000, about U.S. $9,000.

D. The model house is designed of imported materials, using Portland Cement and steel as basic building materials.

E. The proposed design will require a large quantity of imported lumber for forming the roof and structural elements.

F. The proposed design will require the use of skilled carpenters and masons for construction, who are not readily available in the Dhamar Province.

G. Manufacturing facilities will be required to handle the fabrication of concrete blocks. A batching plant will have to be set up for the production of ready-mixed concrete.

H. Consultant's Scope of Services: The following suggestions were made at the start of the Project:

1. All housing units should be designed to resist seismic forces.
2. Units should incorporate as many local building materials as possible in order to lower building costs.
3. Construction should utilize traditional building design and methods.
4. The use of local unskilled help should be incorporated into the design.

I. Consultant Observations: The consultant noted the use of the following design and construction criteria at the SCR:

1. Inadequate attention was paid to structural design for resisting lateral seismic forces. Instead, the traditional use of heavy, over-designed columns, light filler walls, and non-continuous foundations are employed.
2. The concrete block walls are not designed to resist pull-out forces from the heavy columns or to resist rupturing.

3. The walls and columns do not have compatability to resist lateral forces as they have been designed with different moments of resistance to earthquake forces.
4. The proposed designs require highly skilled carpenters for foundation forming and the erection of well-constructed overhead forms for the roof structural system.
5. The use of concrete block in the proposed design requires highly skilled masons, not readily available in the Dhamar Province.
6. The design did not locate the building foundations below grade in order to achieve maximum resistance to earthquake forces.
7. Reinforcing was not placed at the jambs of wall openings, which are required to resist wall rupture.
8. The roof slab does not possess a high degree of diaphram action, which is required to resist lateral earthquake forces.

J. Consultant Recommendations: The consultant has recommended to the SCR the use of low-cost structural design elements that can take advantage of locally available building materials and the use of local state-of-the-art building skills found in Dhamar Province. The consultant has also developed sets of building design and construction details using these locally available building materials. In addition, these details stress the use of unskilled construction labor doing simplified construction methods.

1. The use of continuous foundations below grade would eliminate the following:
   a. heavy amounts of steel and concrete
   b. forming lumber and nailing
   c. skilled carpenters and masons
   d. close tolerances in building elements
2. The use of continuous foundations would provide the following positive building features:
   a. improved seismic resistance
   b. lower building costs, at least 50 percent on the foundation costs
   c. use of local unskilled help with the replacement of trench forms for above grade wood forming.
3. The use of load-bearing walls would eliminate expensive columns and would distribute the vertical steel in the locations where it is needed to reinforce door and window openings, and provide improved support of the roof loads.
4. The elimination of parapet walls noted in some of the model house designs would reduce moments of inertia and lower the cost of the walls at least 10 percent. Parapets are always one of the first building elements to fail and tumble down under strong earthquake forces. The elimination of parapet walls above the roof will provide greater building safety and at the same time lower the cost of the model house.
5. The retention of traditional Yemeni architectural design was strongly urged.

6. A suggested building system using traditional Yemeni building methods with seismic resistant bearing walls has been prepared. The system employs the use of local building materials, soil cement blocks and clay brick blocks. They are shown in the appendix.

K. Brick Design: In the survey of the Yemeni building materials it was discovered that the Sana'a area possessed a modern brickyard, which is producing high strength units. The consultant suggested to the SCR and the brickyard management that they should consider the use of brick block units as an economical method of providing high strength, seismic resistant walls.

Brick blocks are fired clay units that have the same dimensions as concrete blocks with the added quality of being five to ten times stronger than concrete blocks in load-bearing valves (compressive strength). In addition, the brick walls are water proof and do not require plastering or painting as does concrete block. Brick walls are also maintenance-free as compared to concrete block walls.

L. Soil Cement Design: The building design with the most potential, in the view of the consultant, is the design of soil cement block houses. Soil cement blocks can be made of local soil (earth) and portland cement. These blocks are made of seven parts of local soil and one part portland cement, (7:1), and water. The blocks would have strong initial strength and develop greater strength as they age in the walls. For additional durability, they can be waterproofed by plastering or spraying with low cost asphaltic liquids.

The best feature of the soil cement houses is that they will resemble the traditional Yemeni mud brick houses in color and wall design, yet they can have the required seismic resistance.

V. YEMENI BUILDING TECHNOLOGY

A. Building Traditions: The Yemeni builders are unique in the world of architecture. They have developed a national style that is centuries old, and that is not found anywhere else in the middle east. It has the flavor of arabic architecture, yet it is distinctly Yemenite, with castle-like buildings that fill the cities and villages.

The buildings are splendidly adapted to the different climates that Yemen possess. They provide warmth in the cold highlands and coolness in the tropical coast and desert areas.

The traditional materials have been tan-brown stone rubble and mud brick walls that rise two to five stories high.

During the last twenty years, an increasing amount of concrete block masonry walls have been used. However, the traditional Yemeni architectural design has not been altered. These walls are still trimmed with bands of geometric designs at the top of the walls and at floor lines. The wall openings are similarly trimmed. These bands of design are bas-reliefs and are washed in white lime plaster, giving the buildings a gingerbread house appearance.

The Yemeni have also developed unique arched windows of lace-work white plaster, filled with multi-colored glass. The windows, "caramarias", are expensive, costing about $60 to $150 apiece. They are used universally, even the houses in a poor village will have them.

Another design feature is the "fantasy" doors of steel or wood. They have embossed arabesque designs and they are painted in bright reds, greens and blues. The colorful doors and windows are in bright contrast to the tan walls.

Many of the buildings built during the last twenty years of cut stone or concrete block walls still follow these design traditions. The consultant has urged the SCR to follow these design traditions in their proposed model housing units.

B. Construction Materials: The old Yemeni buildings, as previously mentioned are of stone or mud brick masonry construction. The interiors of these walls are plastered with animal dung and then white-washed with lime.

The floor systems are constructed of logs and are covered with heavy mud plaster, giving the floor a series of bumps and ridges. The ceiling below has the logs exposed and is also plastered with dung and lime white-washing.

It was noted that in the villages hit by the earthquake, the mud brick buildings possessed greater resistance to the shocks. Most of the mud brick buildings are not totally destroyed as were the stone buildings. The most common damage noted in the mud brick buildings was usually in exterior wall failure, either rupturing and then falling down or else the walls separated at the corners.

Foundations in the flatlands are of loose stones, sometimes mortared with mud. As a consequence, the earthquake forces ruptured the walls at their base, bringing the entire structure down.

The more contemporary buildings are of cut stone and concrete block. The block walls appear to be plastered in about half of the buildings. The roof and floor systems in the newer buildings are of thin concrete slabs, supported on cast-in-place concrete beams. Some of the newer homes in the rural areas, have wooden beam ceilings instead of the concrete slabs. The beam ends project through the plastered block walls, giving the buildings an American Indian look.

C. Construction Methods: Traditional construction methods used masonry walls without any reinforcing steel. Occasionally, doors and windows are ususally tree branches, plastered over to form part of a door or window frame.

1. Foundations, when they exist, are made of local volcanic rock, with or without mud mortar. The newer buildings use the same rock foundations, except they add a cement mortar to bind them. The consultant pointed out to the SCR that these rock foundations, usually above grade, have zero value in resisting earthquake forces.

2. Contemporary Yemeni buildings, built in the last 15 years, use of post and beam systems. Heavy foundation pads, about a meter square, are cast on grade. They insert nine 2cm bars of vertical steel for the column.

   Between the foundations pads, black volcanic cut stone blocks are laid as footings. They are not an integral part of the structural system. Their function appears to be as a setting bed to support the concrete block or cut stone filler walls. Additional concrete pads are located between walls or in the building interior.

3. The newer buildings also feature cantilevered floor systems. In many cases, the extended floor slab which supports an exterior wall, does not have a rim (edge) beam to support the cantilevered exterior wall.

VI. MANUFACTURING FACILITIES: In the brief survey made by the consultant, it was noted that most construction materials are made in small shops that dot the towns. Most of the shops employ

less than ten men. The work is done with hand tools and simple electrically powered tools. Large presses or machine shop equipment were not evident. Quality control and dimensional accuracy was weak, as the manufacturer left the problem for the contractor to make things work out.

A. WOOD: Items made of wood are windows, frames and interior doors. They are often handsomely made, with refined detailing. The most common wood used is a mahogany type lumber that is imported and expensive.

B. STEEL: Steel is used in buildings principally as reinforcing steel bars, which are imported. Doors and shutters are made of sheet steel, with frames of steel angles. As mentioned, these doors and shutters have fanciful arabesque designs of thin steel strips that are welded to the sheet metal.

Other uses for steel include steel gratings and railings. They are also hand-made in small shops. A few steel web trusses are built, for large span buildings.

Precision made steel building products are all imported.

C. CONCRETE: Concrete products, as manufactured items, are generally limited to tiles and paving blocks. They are made on small hand presses or cast in wooden or steel forms.

Air curing is used. A few of the larger contractors produce precast concrete structural units for their own projects.

D. CONCRETE BLOCK: The manufacturing of block appears to be the largest building industry in Yemen. There are block yards in every neighborhood in Sana'a and apparently in every village. Most of the block yards are three and four men operations, using small electrically powered presses that make one block at a time. The blocks are placed on wooden pallets and air cured.

The SCR stated that there were several operations in the outskirts of Sana'a that had large production facilities and produced high quality units.

E. BRICK: Sana'a has a first class brick manufacturing facility The plant, recently constructed by an Italian company, is totally automated. It is producing brick of the highest quality. The plant produces a high strength unit, uniform in quality, color and dimensions. These units have the capacity to provide walls of the highest strength and earthquake resistance.

The bricks currently being produced are small modular units, which require extensive labor per unit to lay. As a consequence, their marketing has been limited to institutional type buildings, such as at Hada Center.

The consultant suggested to the SCR and the brick manufacturer the possibility of making brick blocks, bricks the same size as concrete blocks in order to bring the labor costs down. This would cut labor costs to the same price as block laying. Both the SCR and the manufacturer are considering the idea. The existing brick equipment has this capacity. The local clay being used is of a high quality and can easily produce the units.

As a result of this finding, the consultant has prepared design details for seismically resistant brick walls. They are attached in the appendix. The SCR stated that they will pursue the use of brick buildings as a way of stimulating local manufacturers.

F. WINDOWS: The manufacture of all types of windows is a widespread industry in Yemen. Generally, all of the manufacturers are small shops, located in every part of Sana'a and in every large village.

1. Wood sash windows are made throughout Sana'a out of a mahogany type wood. Generally, the workmanship is good. They also make the frames to install the windows out of the same material.

2. Steel sash windows are also made in limited quantities, usually by the same shops that make window grills and railings. All of the assembly is done by hand welding.

3. Aluminum sash windows appears to be a growing industry as it was noted that most of the replacement windows in the old homes and buildings in Sana'a are aluminum. The same shops also produce sliding glass doors.

In the designs prepared by the consultant for the soil cement block houses, the use of wooden sash doors and windows is stressed as an economical method of construction. The wooden sash would be placed in its final location in the wall and the mason would use it as a form to start his block laying.

G. DOORS: Door manufacturing is another large industry in Yemen. A visitor's first impression in Yemen might be the fanciful steel doors on every building along the road from the airport. The consultant has suggested to the SCR that this tradition be maintained in the model houses it is proposing to build.

The steel doors are universally used in both residential and commercial uses. This is interesting as they are quite expensive. A small narrow door costs about $200 and a pair of residential doors cost at least $1000.

The doors are constructed in small shops throughout Yemen. The workmanship and quality of the doors is very good. They are constructed of steel angle frames and sheet steel with thin strips of steel creating fanciful patterns on the face of the door. They are always painted in bright primary colors. In buildings with multiple door openings, the same pattern is used in all of the doors, giving the buildings a design harmony.

Wooden doors are another widespread industry throughout Yemen. The shops are also found in every neighborhood. It was noted that their principal use is as interior doors. The doors are made of a mahogany type lumber. Some of the window shops also make the wooden doors.

H. PLUMBING: The only residential products that seem to be manufactured in Yemen are water and storage steel tanks. Again the countryside is dotted with small shops manufacturing tanks out of steel sheet stock. The quality appears very good.

Plastic pipe for water and soil lines is also manufactured in Yemen for domestic uses. It appears that all other plumbing fixtures and equipment is imported.

I. ELECTRICAL: The only electrical products made in Yemen according to the SCR is plastic covered conduit (romex) wire. It is made in well equipped plants.

VII. DHAMAR RECONSTRUCTION PROGRAM

A. FIELD OBSERVATIONS: A site visit to the Dhamar Province to survey earthquake damage was made by the consultant with the assistance of the SCR staff. Representative types of housing were examined for the survey:

1. Stone houses
2. Mud brick houses
3. Concrete block houses

In addition, the different sites were selected in order to study the magnitude and type of damage. They were:

1. Flat villages
2. Hillside villages
3. Large urban development in Dhamar

1. The damage throughout Dhamar Province was typical of a strong earthquake. The un-reinforced walls sheared off at corners and at wall openings. Buildings without foundations moved at the base of the walls and collapsed. Buildings without bond beams (rim beams) had wall separations and often collapsed.

With the failure of the walls, the roofs and intermediate floors collapsed, sometimes killing the occupants.

An important cause of damage was secondary failures, where the house above or adjacent to another house collapsed. The weight and amount of rubble would then destroy its neighbor, even though the secondary house had survived the shock. This was very apparent in the village of Sada, where there was total destruction of the village. It was apparent from some of the structural elements still standing that certain houses would have survived, except for the tons of rubble that fell down on them, collapsing their walls. Then the roof and floor would fail. This type of damage was typical in the hillside villages that were examined.

2. The amount of standing rubble in the villages and the town of Dhamar poses an imminent danger to the safety of the population. Very little of the rubble has been removed and it is producing heavy pressures on the walls of the houses still standing. Some of the rubble piles are four tc ten feet high and are pushing on the walls of occupied homes.

3. Reconstruction has already started on a do-it-yourself basis throughout the region. Collapsed walls are being replaced with block walls, roofs have been added and windows and doors replaced. New homes are being constructed of concrete blocks in every village, adjacent to the destruction.

4. In all of the new work and reconstruction efforts, seismic considerations are lacking.

5. The consultant felt that many of the mud brick houses can be repaired by banding. It is a process using long steel rods, located next to separated walls, that are tightened, pulling the walls together. After the banding, the walls can be repaired. Another common repairing system is to band the entire houses, using heavy steel angles on the outside corners and then welding rods fron angle to angle. This system does not provide seismic resistance, but it makes the house as habitable as the neighborhing houses which did not fail.

6. At this time, the SCR did not have a firm policy on which types of damage should be repaired, or the amount of work and expenses required before a house was to be either saved or demolished.

B. USAID SURVEY PROGRAM

1. The USAID Mission in Yemen is planning to assist the SCR in their efforts to survey the damage in the Dhamar Province.

2. The SCR staff at Dhamar has already started surveying over 2,000 houses of the 27,000 scheduled for assessment.

3. It appears that it will require about 30 minutes per house to make an assessment of the damage and possible corrective work.

4. The consultant's opinion is that it would take an eight man crew at least five months to make the survey. The World Bank Report estimated a ten man team would require ten months to complete the assessment.

5. The consultant is suggesting that the survey team be half Yemeni and half American architects and civil engineers, and of intermediate skills and experience. It is also suggested that as soon as the assessment is codified and worked out, that the American team could leave the remainder of the survey to the local SCR staff.

6. The consultant has prepared a suggested survey program and survey form to be used by the USAID survey team. It is located in the appendix.

VIII. CONCLUSION AND RECOMMENDATIONS:

A. The consultant suggests that the following points should be considered as part of the Reconstruction Program:

1. The survey should be completed as quickly as possible.
2. The SCR should consider the use of traditional Yemeni design in the architecture of the model houses.
3. The SCR should consider using locally available material as the major construction material, such as soil cement bricks or clay brick blocks.
4. All houses should have:
   a. continuous foundations
   b. continuous bearing walls
   c. foundations below grade
   d. jamb reinforcing at all wall openings
   e. single row (whyte) masonry walls (one unit wide)
   f. bond beams (rim beams) of concrete
5. The use of stone or rock foundations should be banned.
6. The use of wood bond beams (rim beams) should be banned.
7. The use of stone masonry walls should be banned.
8. Require inspection during construction of all houses.
9. The SCR should consider the use of Computer Aided Drafting Systems in order to meet its architectural, Village Planning and engineering deadlines.

YEMEN ARAB REPUBLIC

REPORT OF

EARTHQUAKE RECONSTRUCTION

JOINT MISSION

PROPOSALS FOR A RECONSTRUCTION

PROGRAMME

February 25, 1983

vii, The Mission wishes to express its thanks and gratitude to the Government of YAR, in particular to H.E. the Prime Minister, and H.E. the Minister of Development and Chairman of the CPO and all the staff of the CPO and other ministries and bodies, for the assistance and many courtesies extended to it during its stay in YAR.

viii. The Mission also wishes to acknowledge with thanks the contribution made to its work by all those persons whom the Mission interviewed and who generously provided the Mission with information, documentation and comments, and constructive views and ideas.

ix, This report reflects the views of its authors and not necessarily those of the institutions they represent.

THE RECONSTRUCTION PROGRAM

SUMMARY

1. The Government of YAR needs to start the reconstruction effort as soon as possible to alleviate suffering and rehouse the population affected. This will involve (i) the repairing and rebuilding of houses and infrastructures (ii) assisting farmers with seasonal loans in the short- and medium-terms, and (iii) implementing development projects for the region in the longer term.

2. Total cost estimates for the reconstruction program as worked out come to about YR 2.8 billion (US$620 million) of which about 50% is in foreign exchange and 50% in local currency. The cost of Government contribution comes to about YR 1.75 billion (US$3.89 million) about 50% of which is in foreing exchange and the balance in local currencies.

3. Because of the difficult economic situation the YAR is going through, the Government will need substantial external aid inflows of foreign exchange to supplement expected short falls in local resources. This will be needed to (a) cover the costs of Government contribution to the program, and (b) Generally, support the balance of payments and alleviate further strains on the economy.

IV. The Reconstruction Program

23. The proposed reconstruction program is divided in three phases. The first phase or emergency phase includes all the actions that can be swiftly implemented with minimum logistical support and can bring substantial further relief to the affected population. The second phase, or reconstruction phase proper, which runs in parallel with the emergency phase, is geared at providing minimum earthquake resistant shelters to the homeless population. The third phase links the reconstruction program to the development of the Dhamar province as well as to national objectives.

A. The Emergency Phase.

24. The emergency phase covers the period up to the end of 1983. It can be considered as a continuation of the relief operation phase and aims at addressing the most urgent problems created by the earthquake with the exception of the reconstruction of homes and infrastructure. Within this phase the following actions should be undertaken:

(i) The cracked buildings in the devastated area should be inspected by qualified engineers in order to determinate whether they could be safely re-occupied. As mentioned in para. 19 (v), 14,000 of these buildings are considered as safely habitable. Repairs will be necessary, but they can be carried out while the buildings are occupied. If such an operation can be implemented successfully, about one-third of the affected population could be rehoused in the very near future.

(ii) Technical advices, both on the type of earthquake resistant constructions and on siting should be provided to people who are already rebuilding or plan to do so soon. Technical picture books with minimum written script, which explain the principle of earthquake resistant construction, should be disseminated (they have been left by the joint mission with the Central Planning Organization). The traditional mass media, and particularly T.V. should be mobilized to spread this information further.

(iii) The rubble should be cleared and the buildings which appear about to collapse should be propped up to allow for safe access into villages. This will ease up the task of the advisers mentioned above and enable the population to retrieve safely their belongings as well as building materials from the rubble.

(iv) New sites to rebuild villages that have been fully destroyed because of poor location should be identified. This very delicate operation should start very early to capitalize on the goodwill of the population to find solutions to land tenure problems in view of the urgency of the reconstruction. The Local Development Associations should be involved in this process.

(v) Farmers of the earthquake - stricken area should be provided with seasonal loans to ensure the next crop and enable them to reconstitute their lost capital (mainly hand pumps and cattle). Since the next crop season is imminent (March/April 1983), such measure will help maintain or even increase their income and enable them to take up reconstruction loans if needed (para. 25).

Table 2

Some of the recorded mainland earthquakes in the history of Yemen*

Hegira Mn.	Hegira Yr.	A.D. Mn.	A.D. Yr.	Areas and Description
	212		827	From Sana'a-Aden and all over Yemen; many houses and villages affected.
	245		859	Cities destructed, springs disappeared.
3	540	9	1145	Destruction of towns, villages, palaces, loss of human and animal lives.
4	549	7	1154	Destruction of houses, villages, loss of lives.
9	601	5	1205	Felt all over Yemen, western side in particular.
	1029		1620	Sana'a-Sada'h area, all over Yemen, many tremors.
	1039		1630	Sana'a area.
12	1056	1	1647	Sana'a area.
9	1077	9	1667	All over Yemen.
5	1085	9	1674	Dhoran area, about 30 shooks.
	1086		1675	Dhoran area, Sana'a, continued for few minutes.
	1090		1679	) Sana'a area.
	1090		1679	) Sada'h area.
	1090		1679	) Mokha area.
	1342		1925	) Sada'h area.

*Compiled from different sources.

14. The total number of earthquakes records issued by U.S.G.S., that took place in YAR or adjacent areas (10-20 degrees North, 40-50 degrees East) for the period between January 1953 - December 1975, amounted to 69 earthquakes. Their magnitude ranged between 4.4-6.4 RS; their focus were less than 70 km. Three of them struck YAR mainland (UNDRO report).

Date	Origin Time			Lat.	Long.
	Hr	Mn.	Sec.		
1955 March 03	00	43	40.2	14.46°N	41.29°E
1959 Aug. 16	13	31	15.1	14.52°N	43.41°E
1965 Oct. 17	20	08	53.1	17.20°N	43.70°E

15. On December 14, 1975, two earthquakes have been felt in the Yemeni coastline although they occurred 60 km. offshore. Another earthquake has been felt all over YAR, took place in 1980.

II. Dhamar Province Earthquake

A. Seismotectonic setup of Dhamar Province

16. As it has been indicated in para. 5 and Figs. 4 and 5, major active oblique strike slip fault run through the area. They extend from Dhamar to Raa'da through also the quaternary volcanic massif in the south; this system is intersected by a northeast-southwest faults trend. (Fig. 8). The area was and still affected by tensional tectonic forces. Faults and fractures occurred with various trends. The following are the geological formations that form the geologic column of Dhamar area given by increasing age: -

Trap series, Tawilah group, Amran series, and crystalline basement.

B. Earthquake occurrence

17. At 12.14 hours local time (09.14 G.M.T.), all over YAR was shaked by an earthquake of 5.8-5.9 on RS and about VIII on MMS. The focus was Dhamar Province, Ma'abar region, latitude 14.6°North and 44.2°East; the epicentre was held fixed at 10 km. After shocks have continued to occur in the province

Table II-3: Damage Causec to Water Resources in the Dhamar Province 1/

Nania	ANS	Jharan	Al Hadaa	Magrabe Ans	Dhoran
Number of Villages	214	42	195	154	262
Number of Springs	113	7	43	156	201
" " " dried	5	3	1	5	-
" " " clogged	3	-	-	-	8
dreaced output	1	-	1	2	5
Number of wells	76	33	219	-	23
" " collapsed	11	6	22	-	3
" " cracked	5	-	-	-	-
Number of deep wells	86	16	29	6	6
" " " " collapsed	-	-	-	-	-
" " " " dried	1	-	-	-	-
" " " " lower level of water	6	-	1	-	-
Number of deep wells not identified	38	8	15	-	6
Water Pipes	43	2	10	6	11
" " partially broken	2	-	-	-	7
" " totally broken	-	1	-	1	-

1/ Source CPO estimates. Partial Survey.

18 Finally the damage caused to agriculture was minimum. Little of the cattle or stored crops was lost and few terraces collapsed.

C. Missions Findings, Assessment and Conclusions

19. The missions findings, assessment and conclusion can be summarized as follows:

(i) The cause of the earthquake and future possible recurrence is still and is likely to remain controversial. It is, however, the opinion of the Mission that the cause of the earthquake has been due to a mild seismic activity (along the oblique strike

slip faults (para. 7) and/or in the deep seated tectonic zones) accompanied by volcanic activity. Such activities are settling down.

(ii) the Yemen Arab Republic can be considered as a zone where both mild seismic and volcanic activities can occur at any time and any place. It is the opinion of the Mission that all areas in YAR can be subjected to the consequences of such activities.

(iii) The Mission concurs with the Government overall estimates of the physical destruction, but has retained a 20% margin of error for cost computation purposes.

(iv) The Mission believes that the extent of the destruction was not so much caused by the strength of the earthquake but was mostly due to the poor construction, deficient design and odd siting of the buildings.

(v) The Mission concluded that about 14,000 of the cracked buildings (out of the 27,000) could be reoccupied immediately, if their owners (who are presently concerned about the possible collapse of these buildings as tremors are still being felt in the area) could be reassured of the soundness of their dwelling by qualified engineers.

(vi) The Mission concluded that earthquake resistant dwellings can be constructed using the traditional building materials, in particular stones. Most of these materials can be retrieved from the rubble, provided a systematic clearance and propping scheme can be carried out to provide safe access to the collapsed buildings.

ANNEX V
Fig. 6

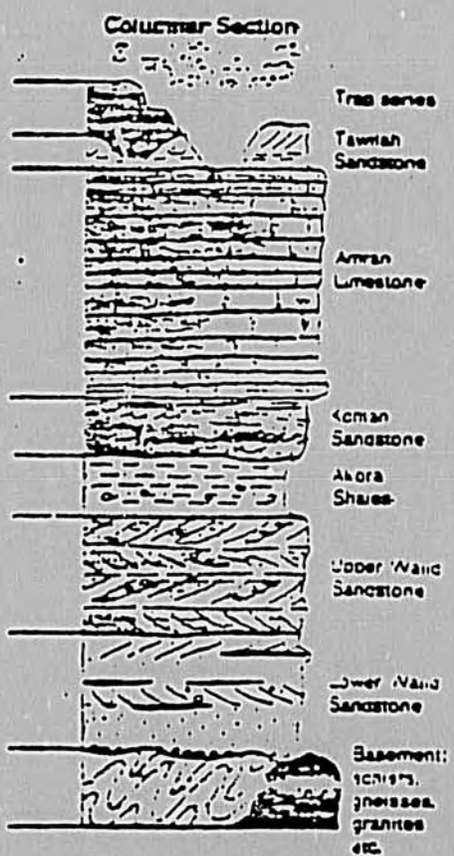
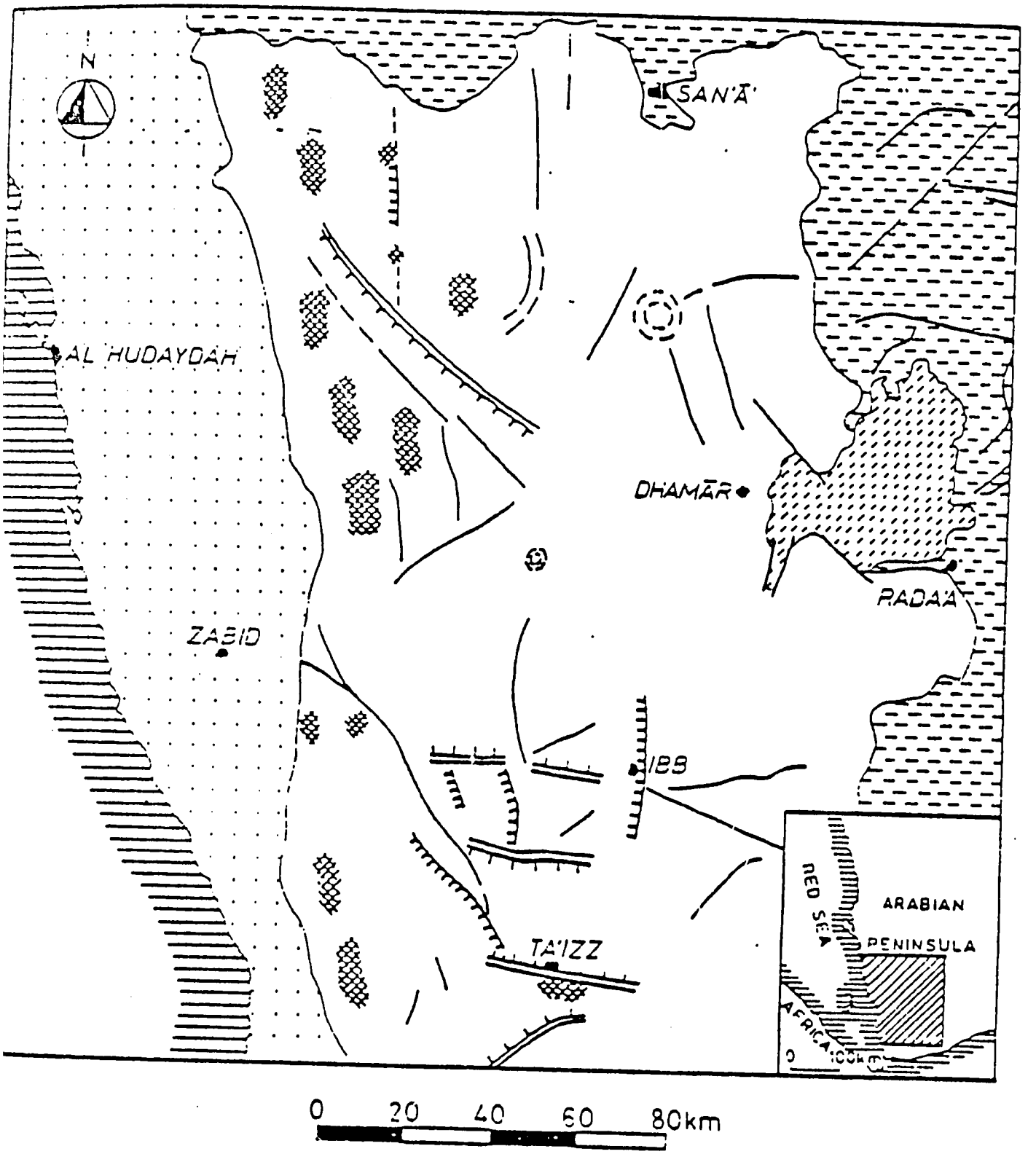


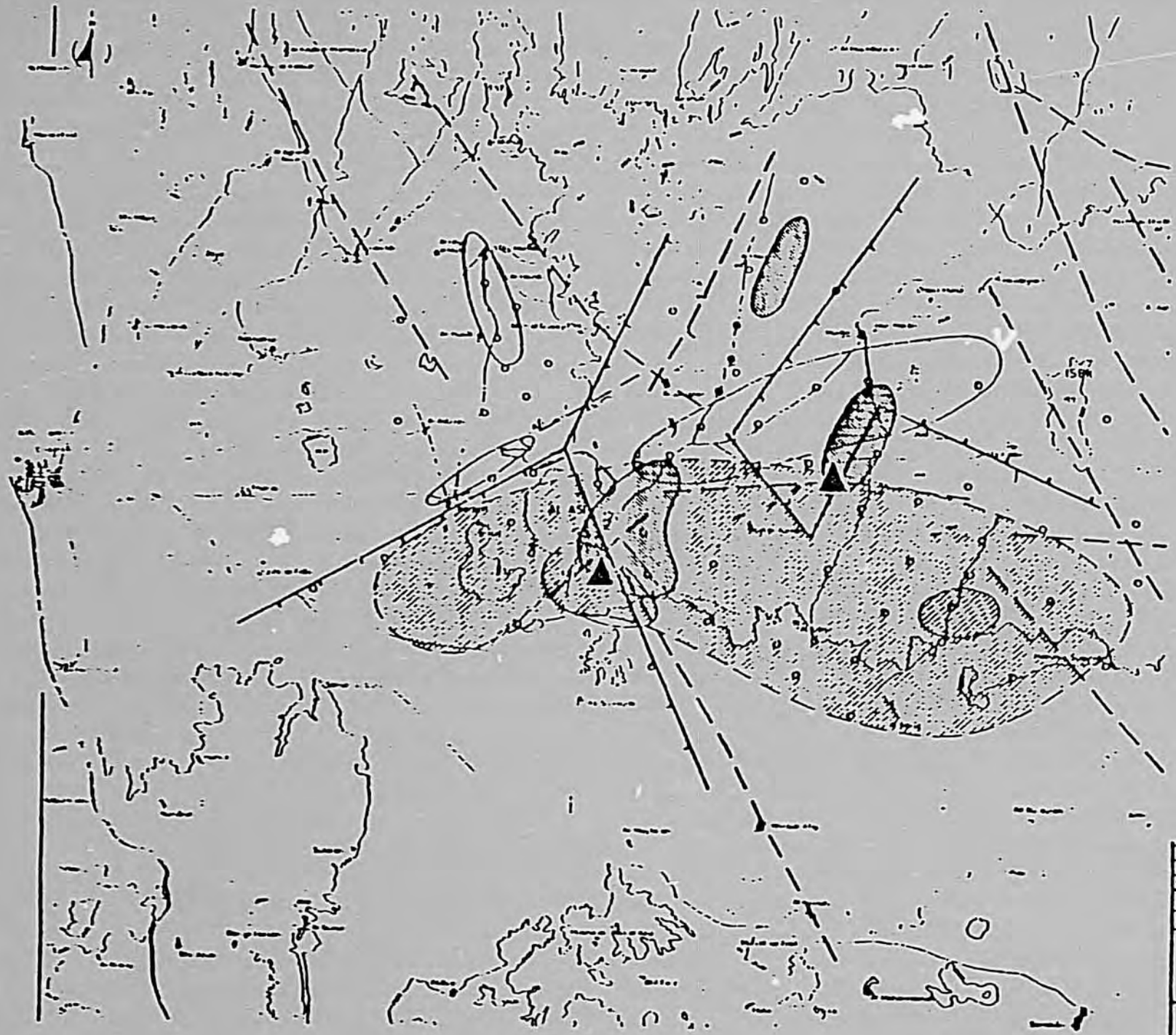
Fig. 6



LEGEND

Area covered by recent sediments
Area covered by recent volcanics
Area of deposition of the Trap Series
Area without deposition of the Trap Series
Main intrusive bodies (granites)
Major faults
Normal faults with important throw
Faults with tilting of blocks

FIGURE 7.

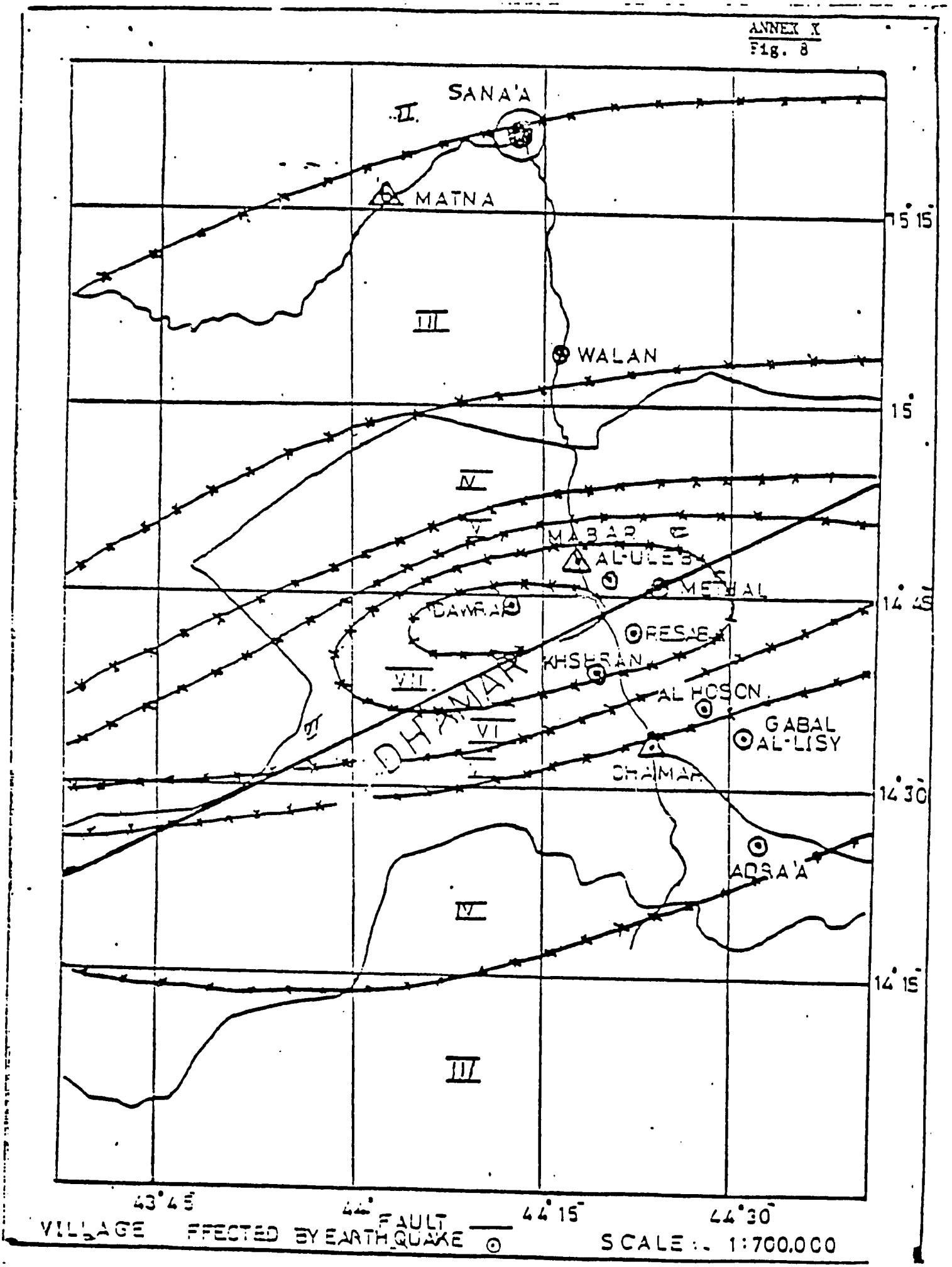


ANOMALOUS ZONES OF GEOTHERMAL INTEREST

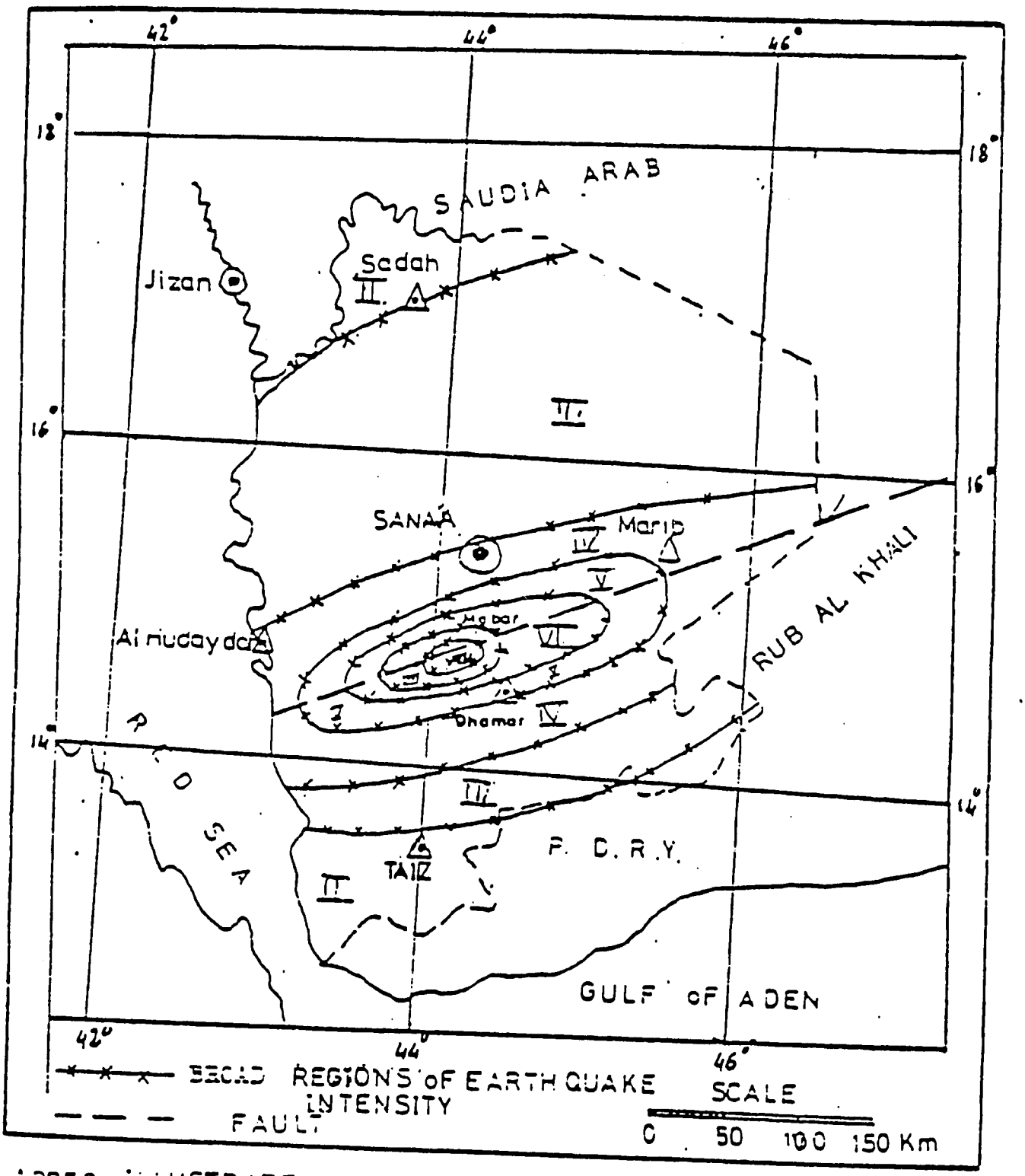
YEM 1001

Fig. 5

ANNEX X
Fig. 8



ISOSEISMIC MAP FIG. 8



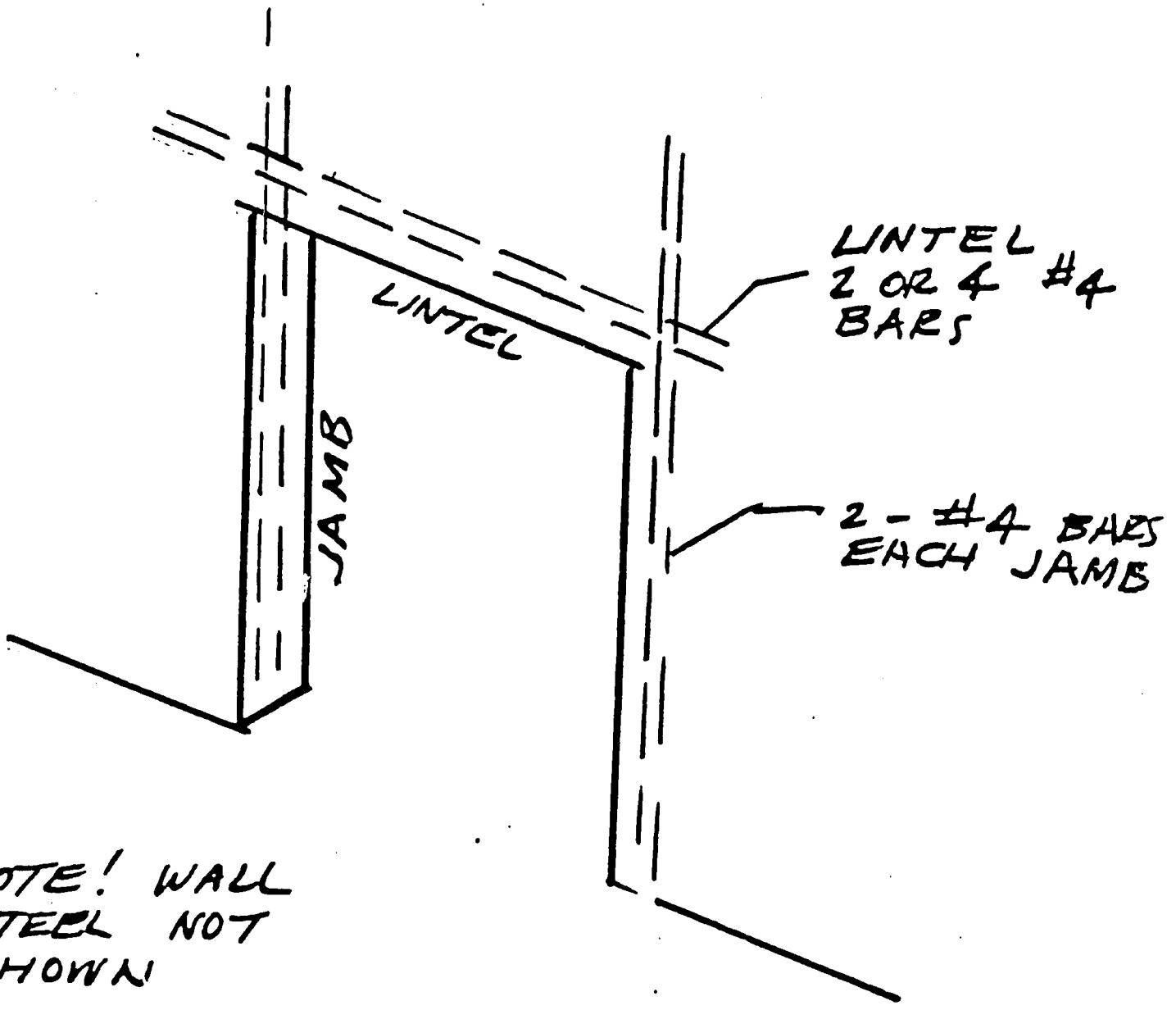
Approx. ILLUSTRATE DISTRIBUTION OF EARTHQUACKE INTENSITY ON MONDAY 13/12/1982 FIG. 9.

HOUSING

SEISMIC DESIGN DETAILS FOR CLAY BRICK MASONRY

WALL OPENINGS

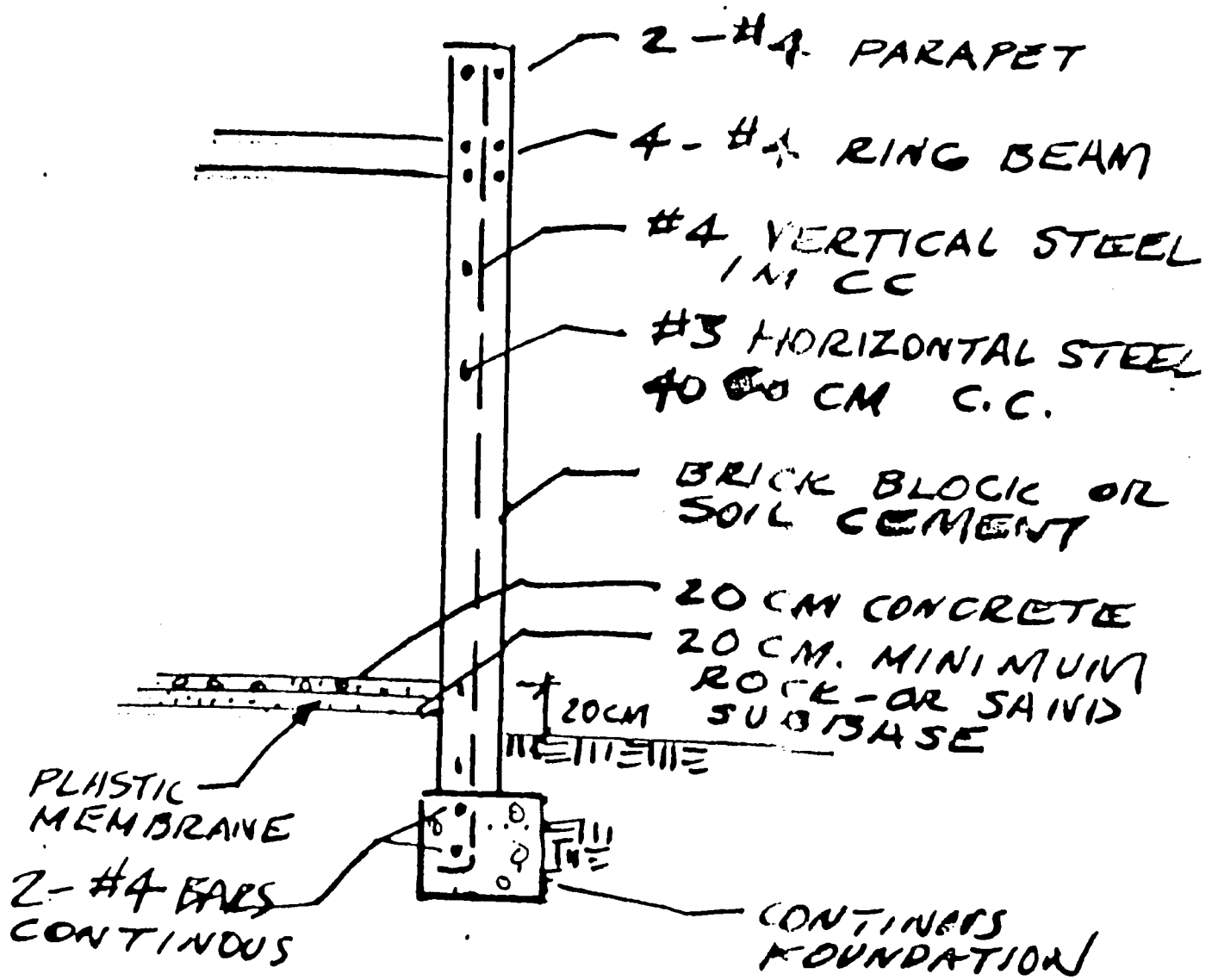
WINDOW OPENING IS SIMILAR



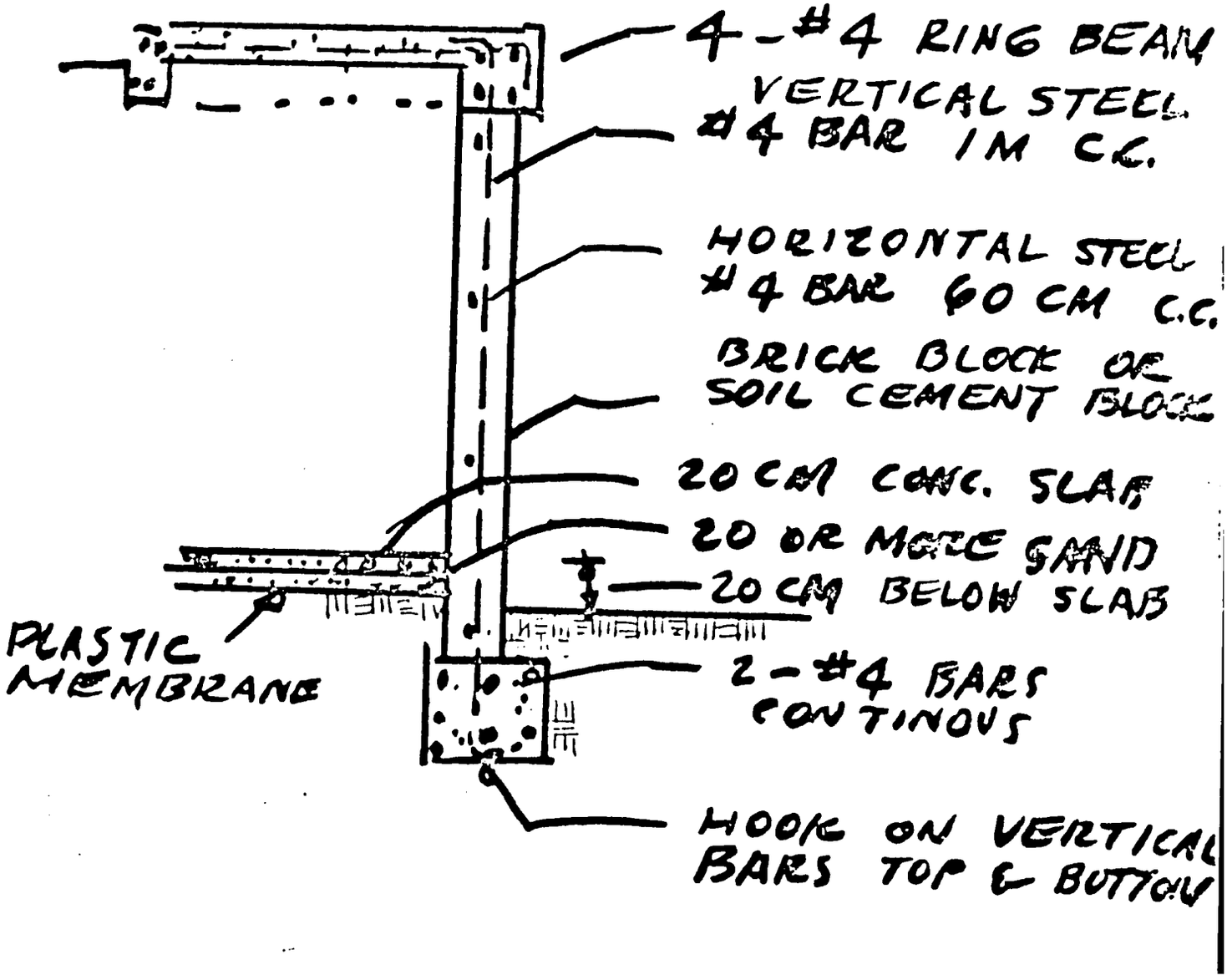
NOTE! WALL STEEL NOT SHOWN!

WALL SECTION

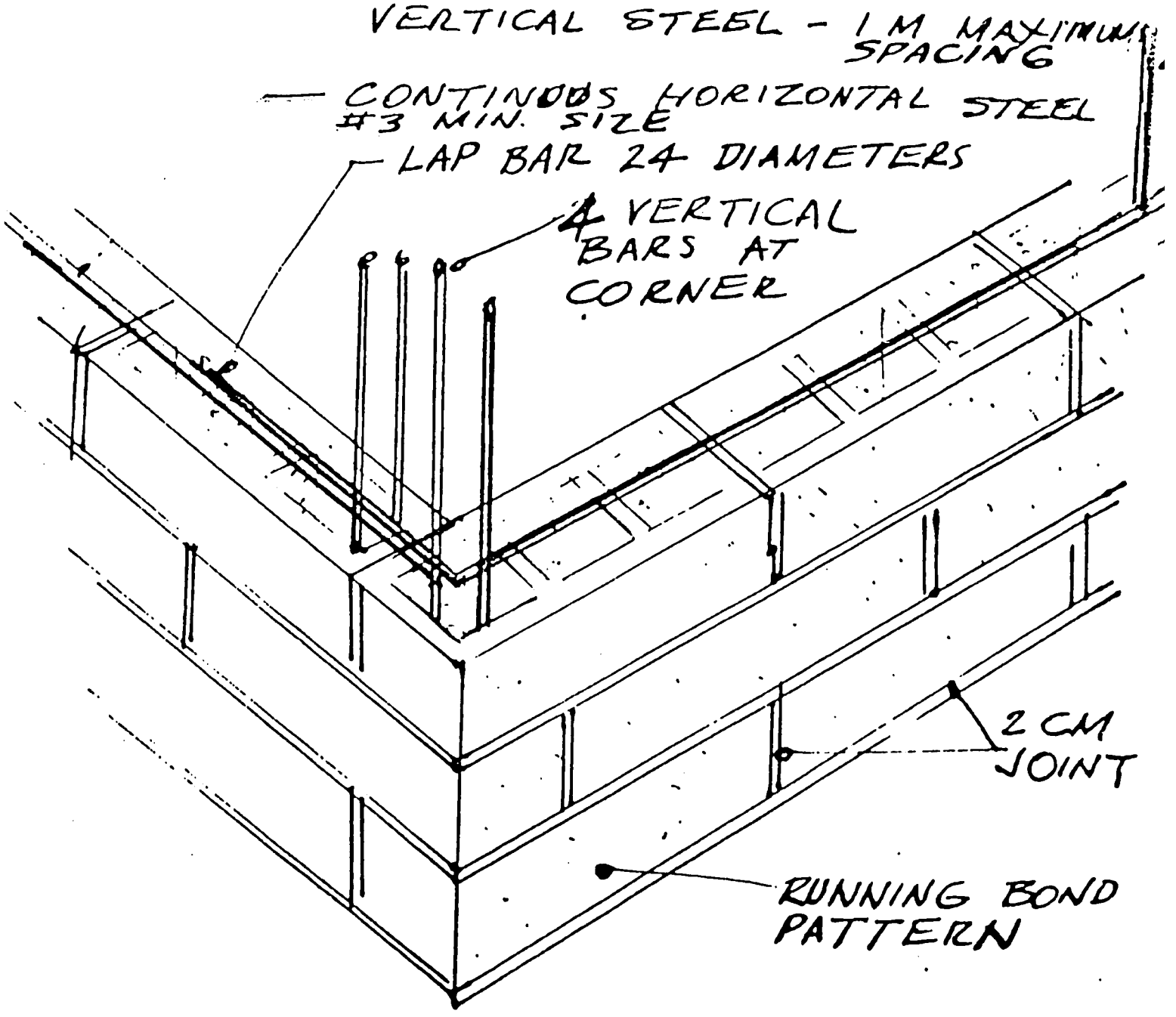
PARAPET WALL



WALL SECTION

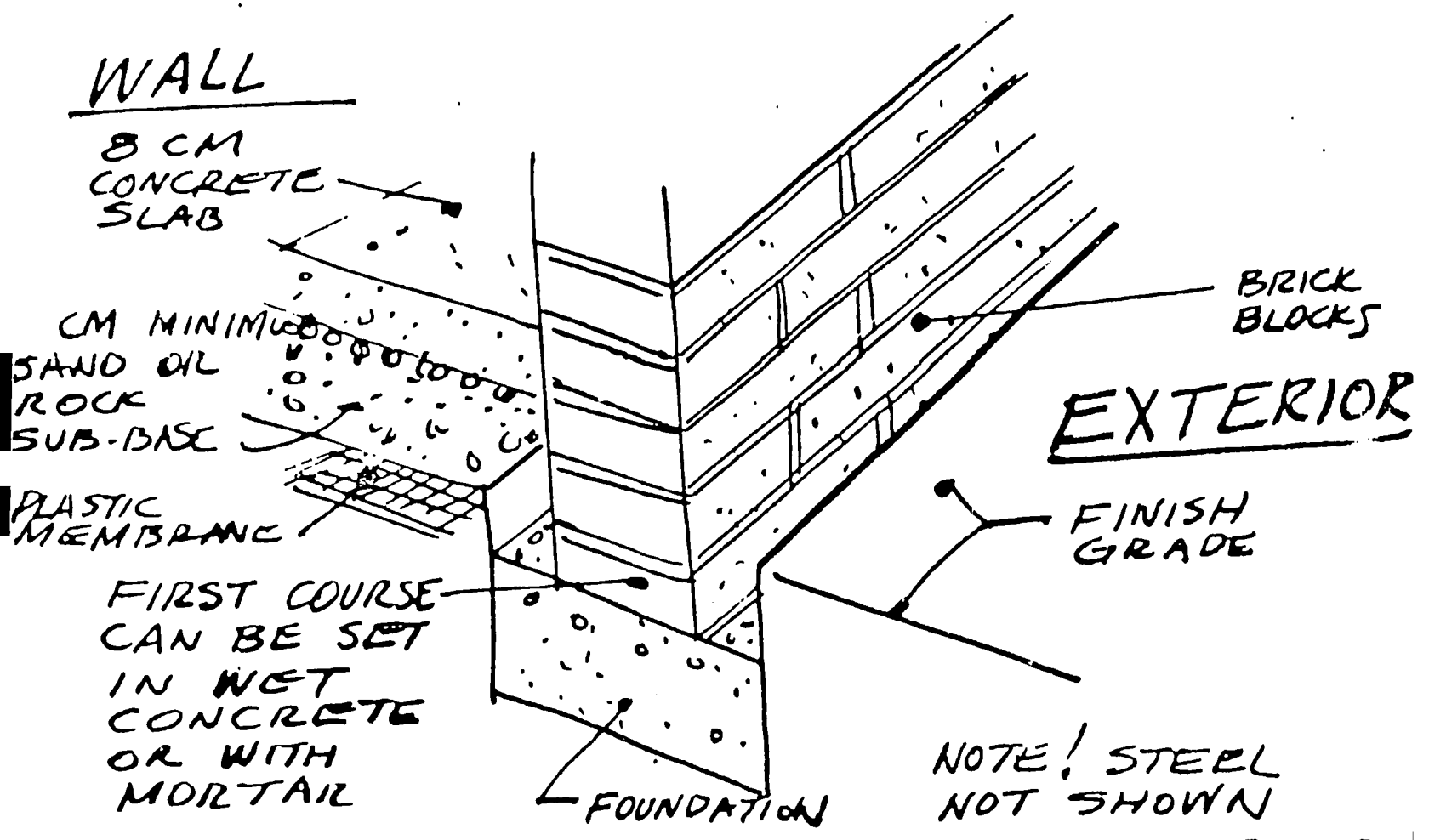


REINFORCING STEEL IN WALL

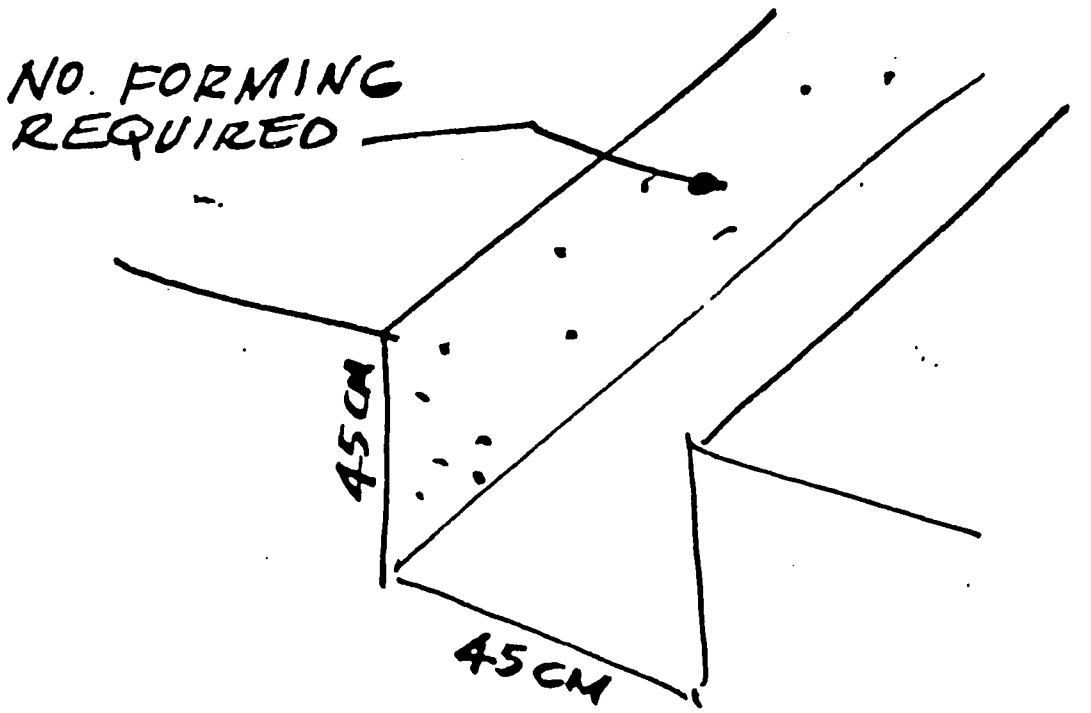


NOTE! VERTICAL CELLS WITH STEEL MUST BE GROUTED SOLID.

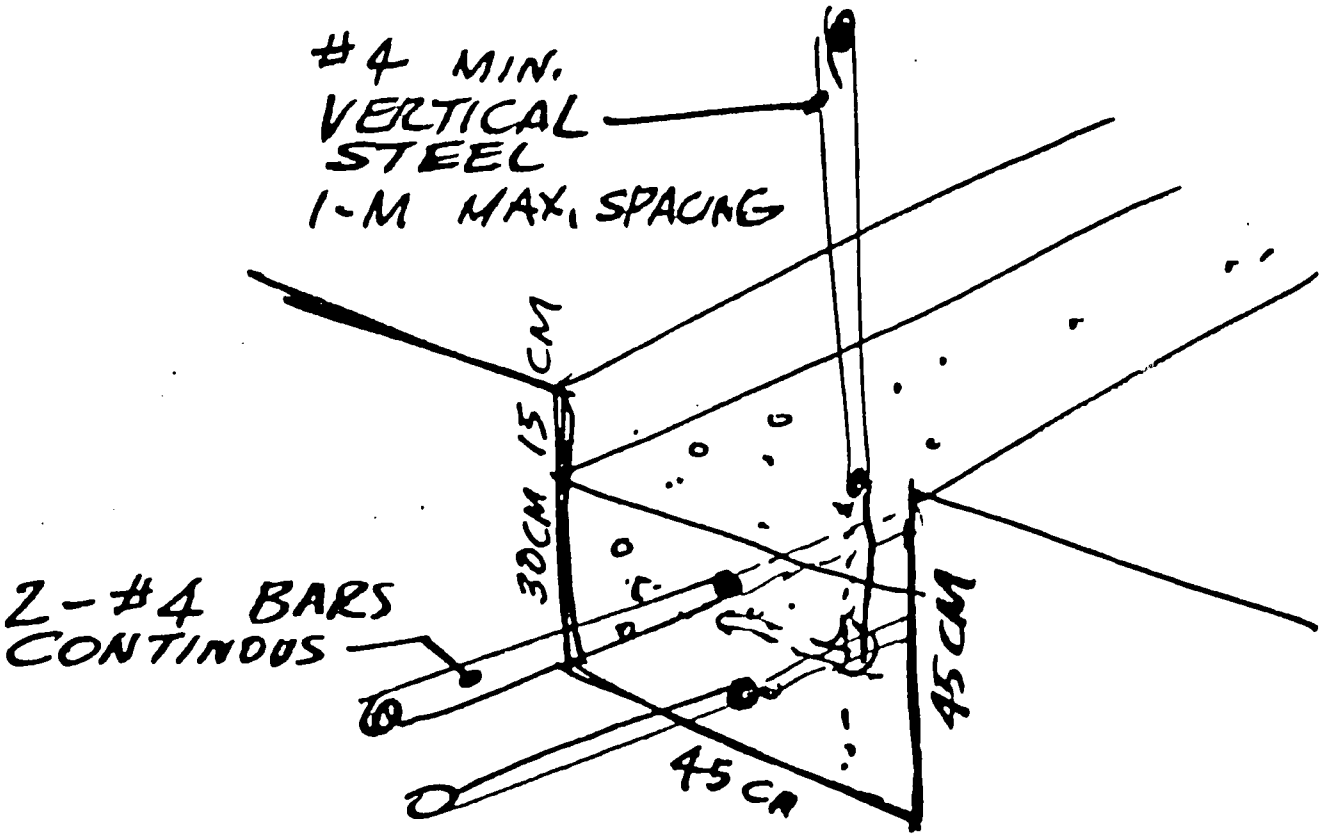
WALL AND FOUNDATION



FOUNDATION



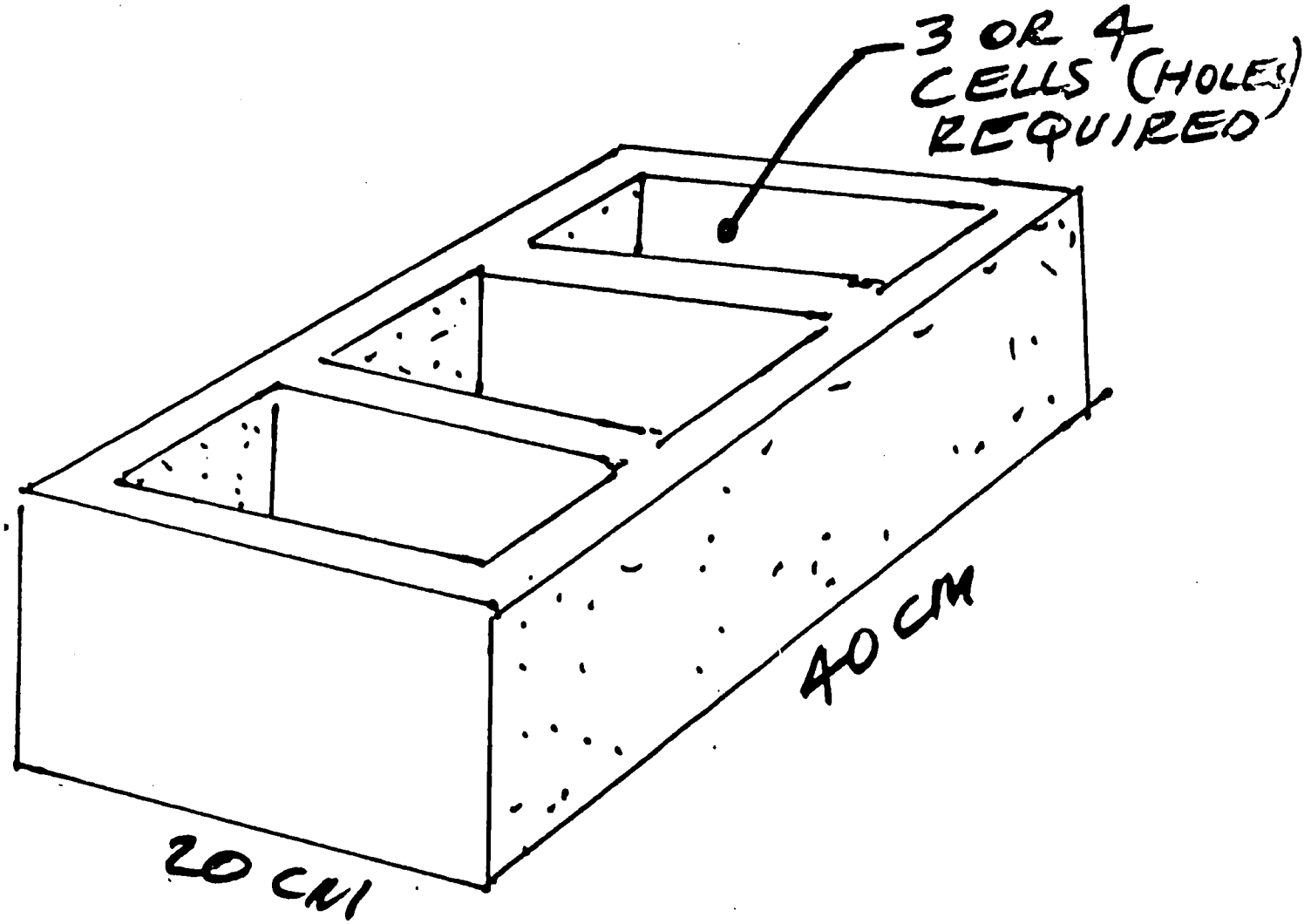
FOUNDATION TRENCH — 1 STOREY BUILDING SECTION



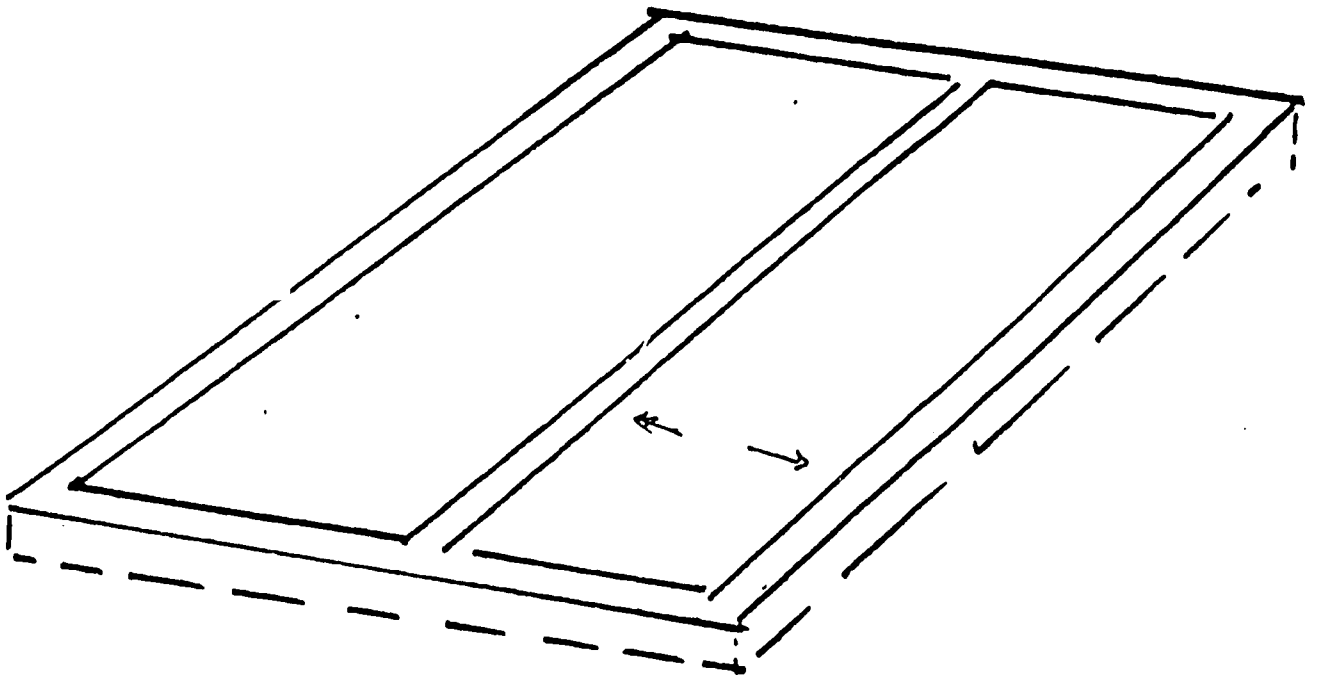
CONCRETE FOUNDATION — 1 STOREY BUILDING SECTION

BUILDING UNITS.

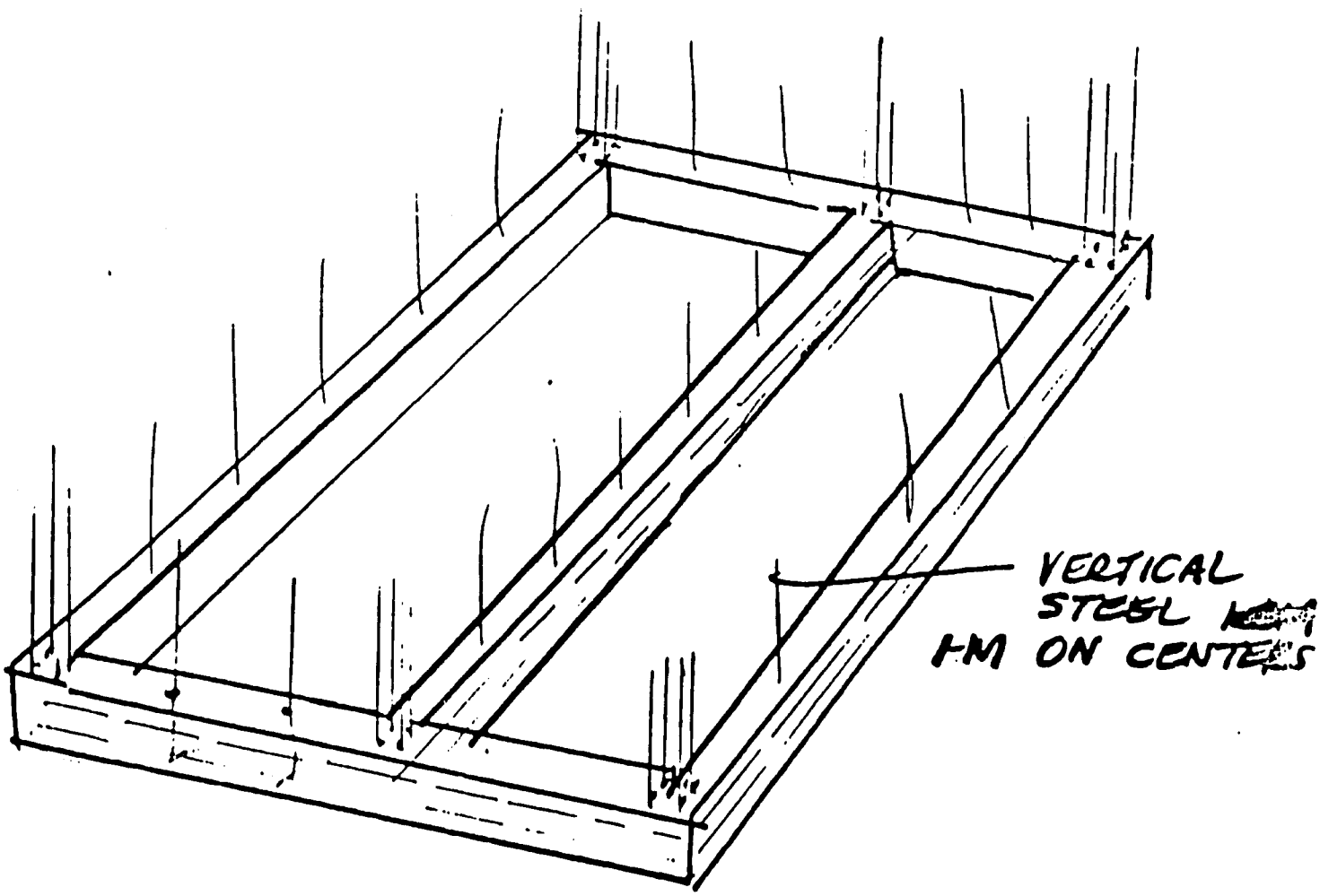
PROPOSED
BRICK BLOCK



FOUNDATION:



CONTINOUS FOUNDATION



REINFORCING STEEL

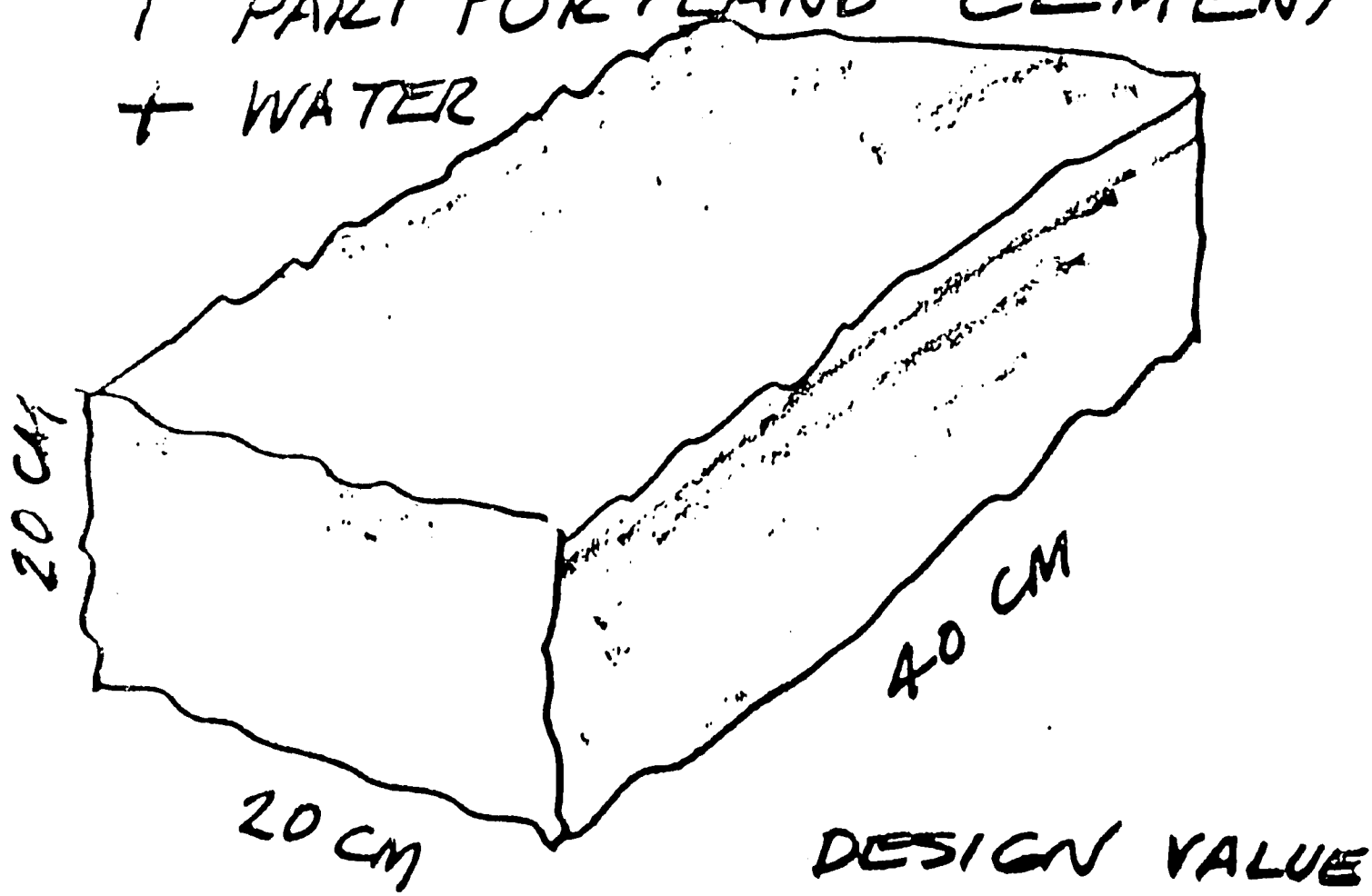
HOUSING

SEISMIC DESIGN DETAILS FOR SOIL CEMENT MASONRY

BUILDING UNIT

PROPOSED SOIL CEMENT UNIT

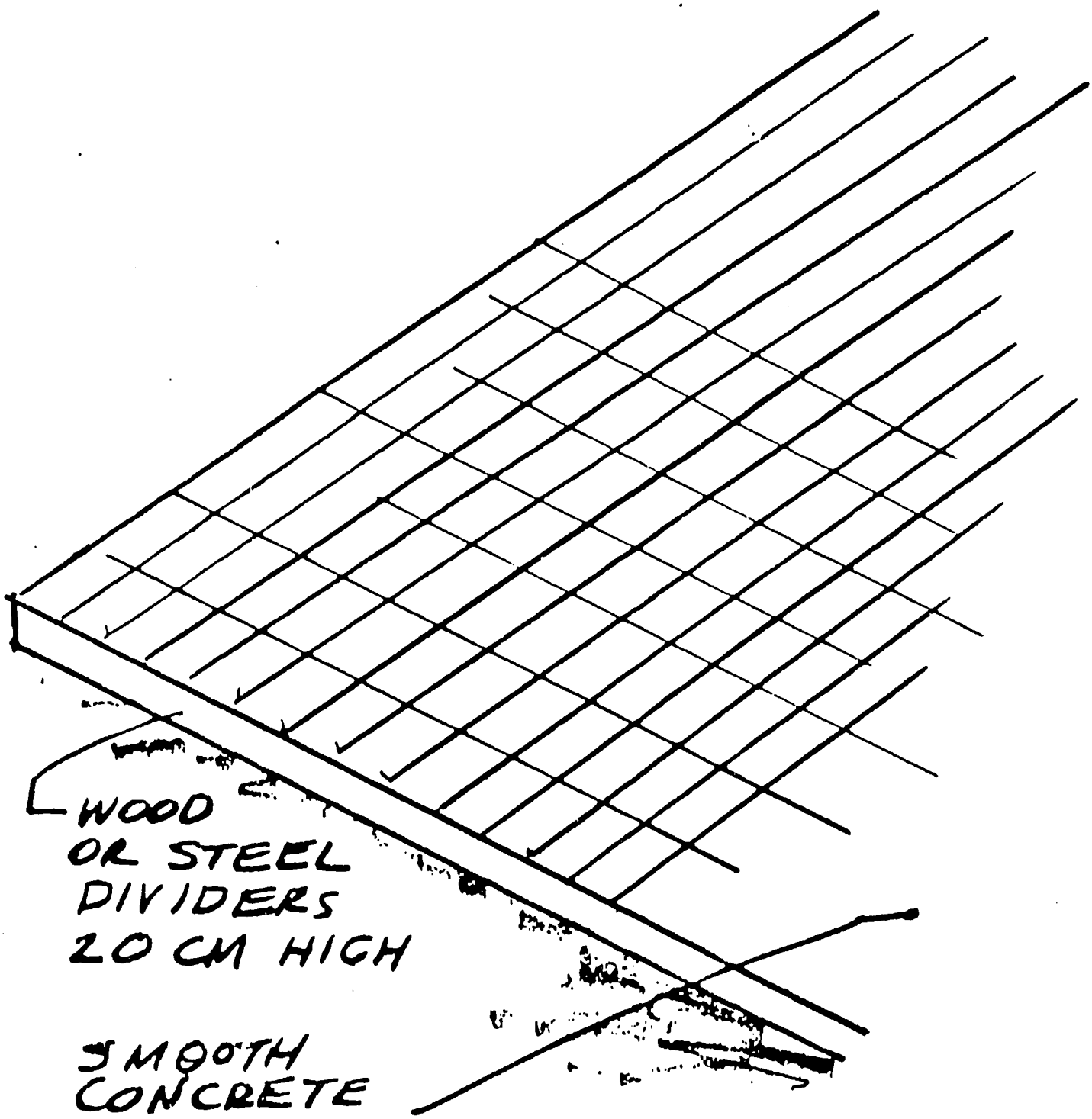
7 PARTS EARTH
1 PART PORTLAND CEMENT
+ WATER



DESIGN VALUE

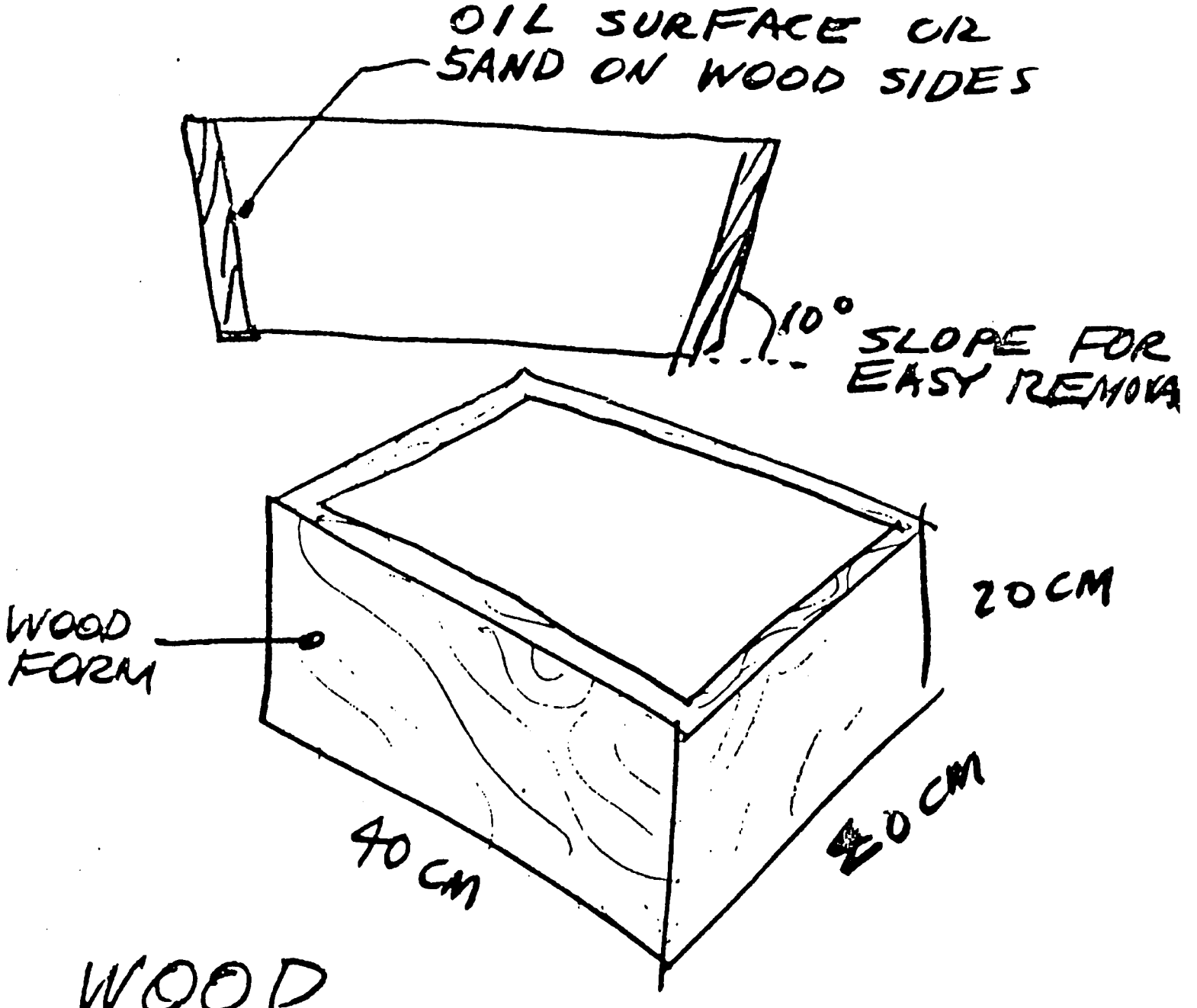
MANUFACTURING

MULTIPLE UNIT SYSTEM



MANUFACTURING

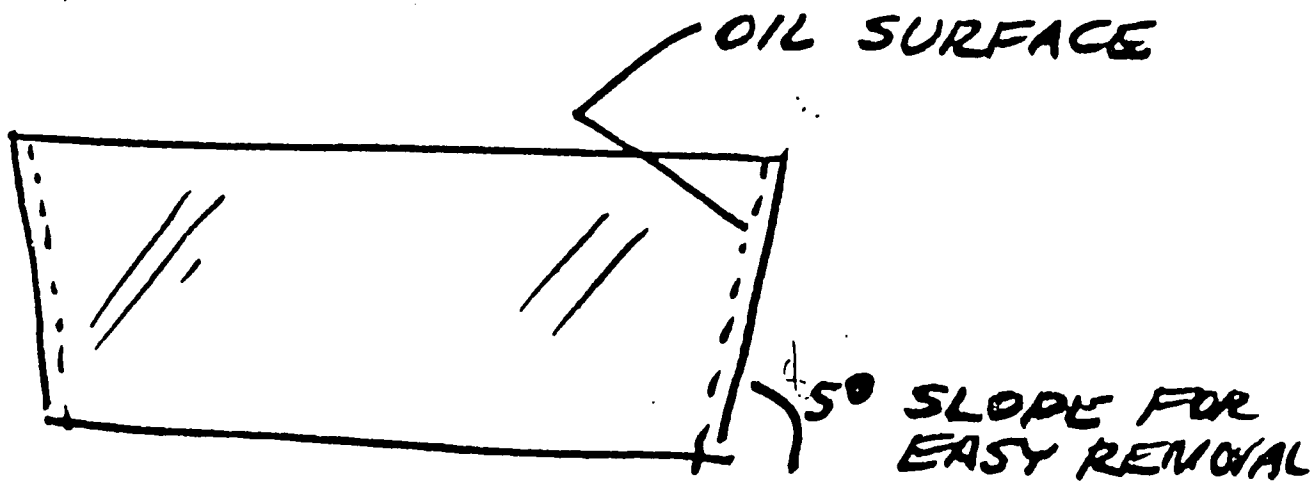
SINGLE UNIT SYSTEM

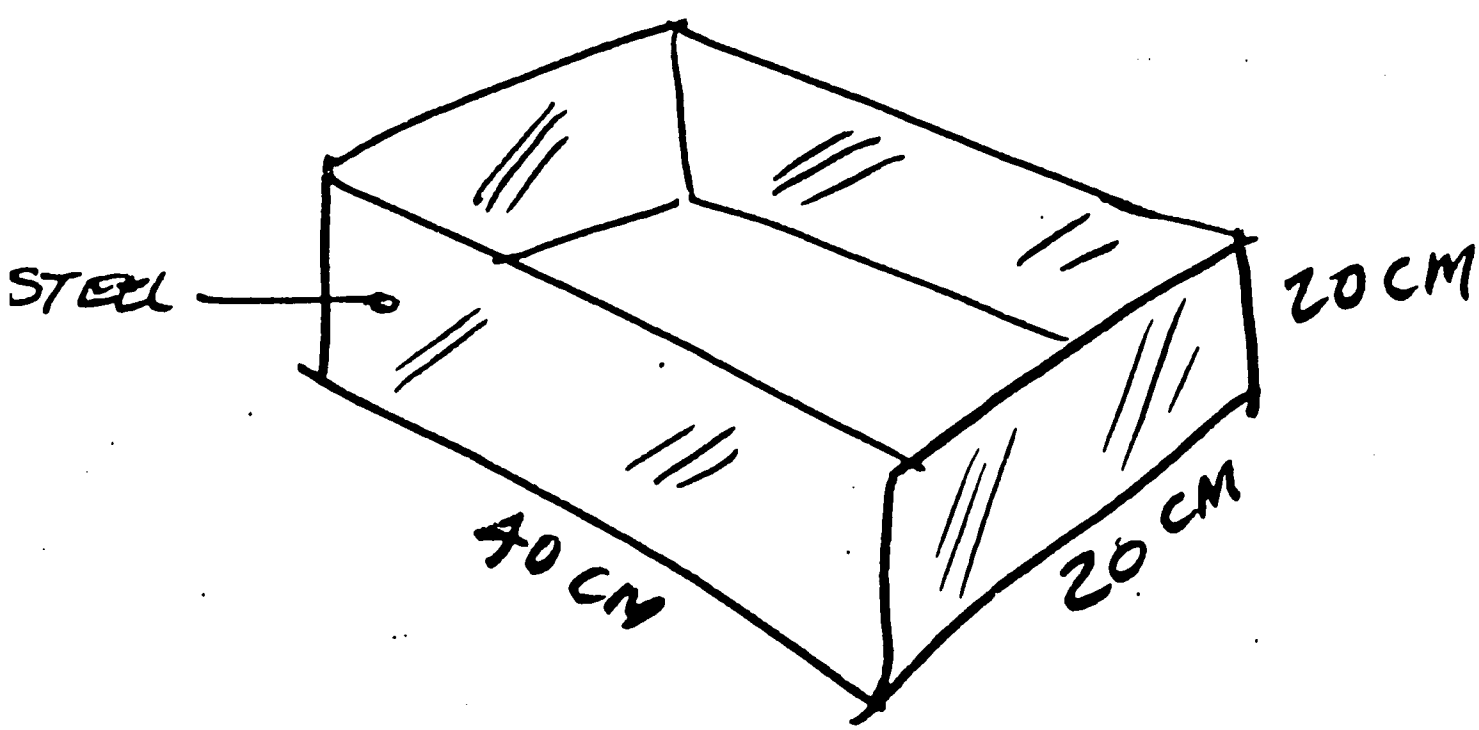


WOOD FORM DETAILS

MANUFACTURING

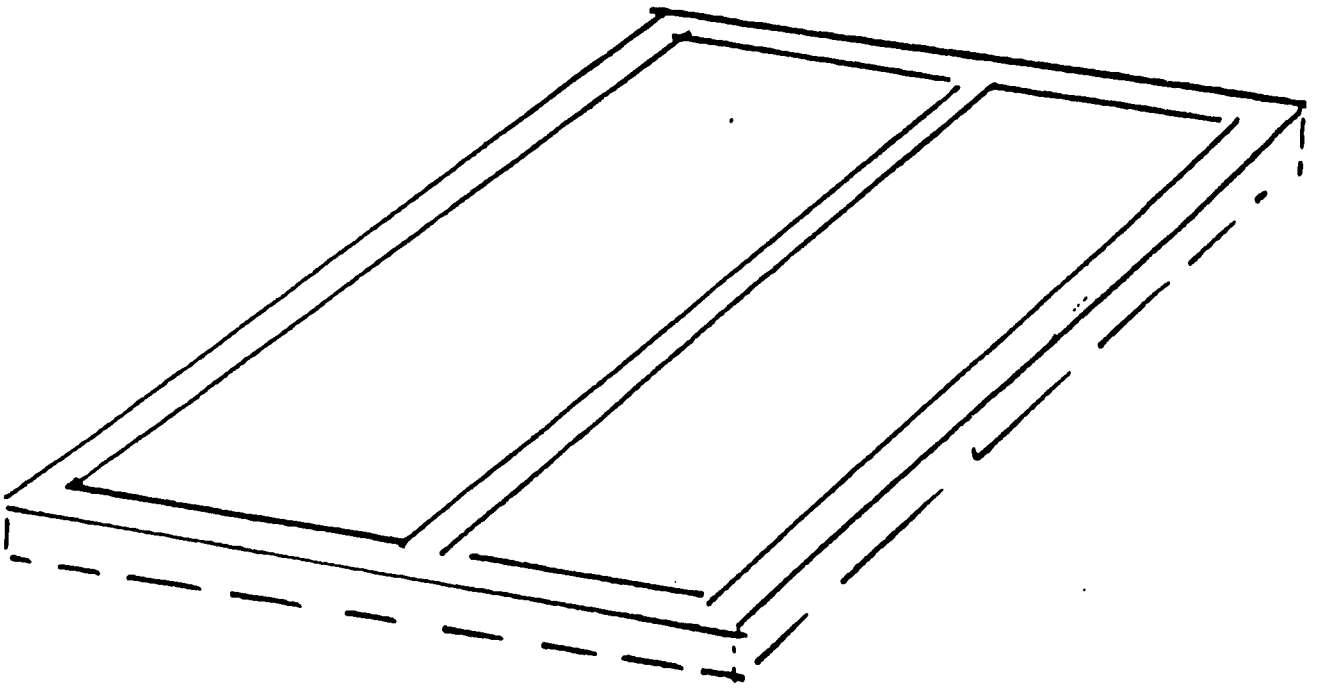
SINGLE UNIT SYSTEM



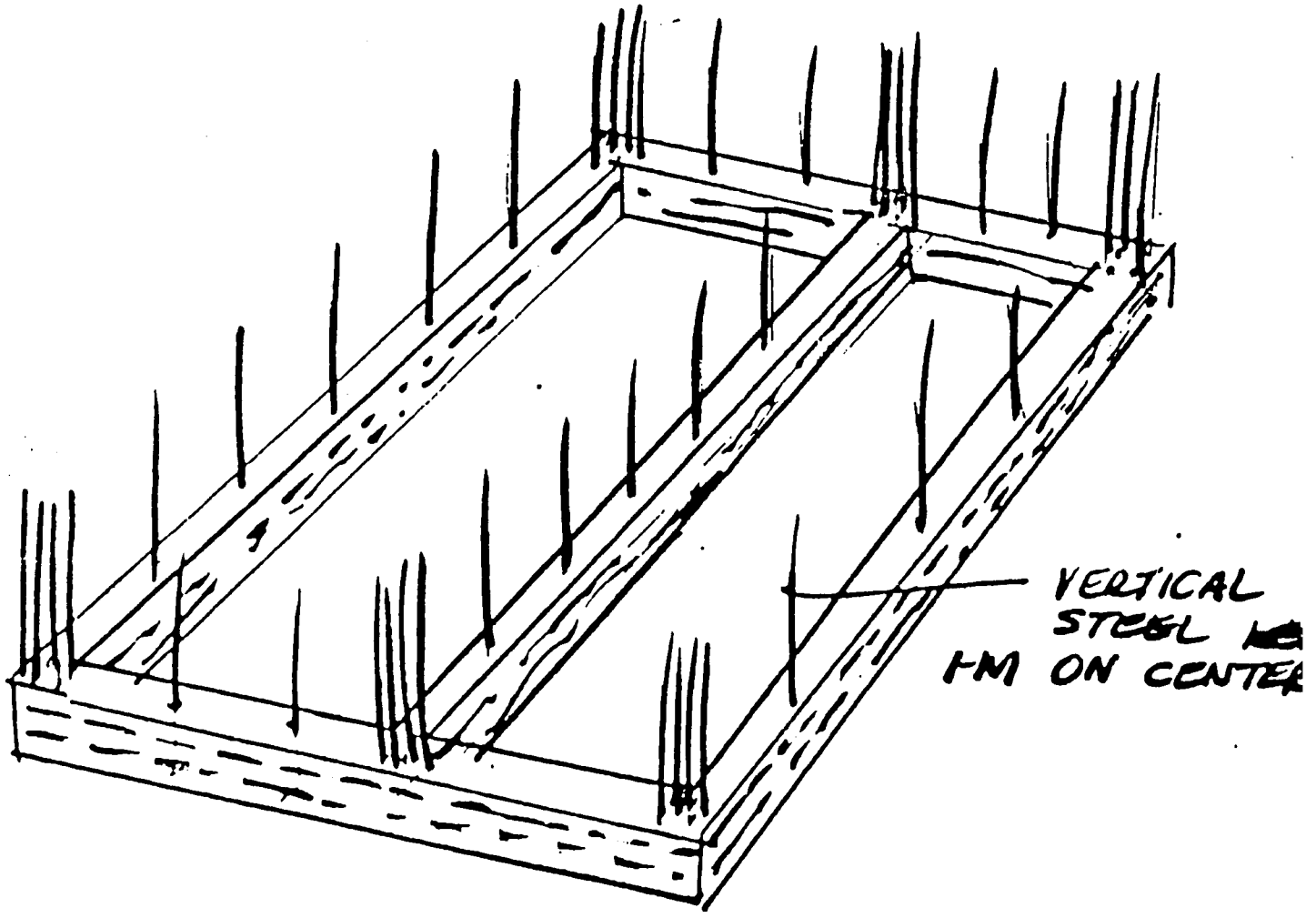


STEEL FORM DETAILS

FOUNDATION



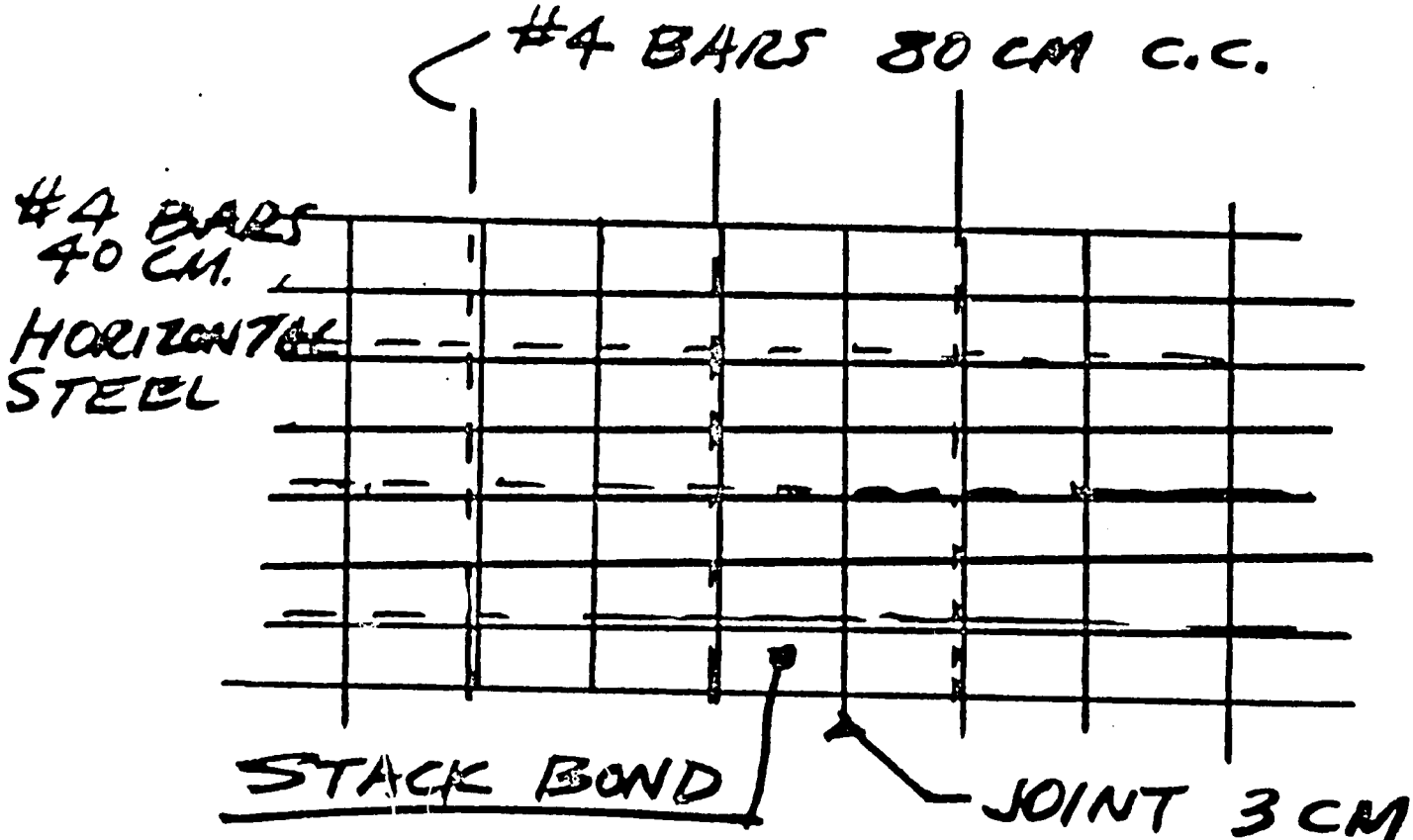
CONTINOUS FOUNDATION



REINFORCING STEEL

WALL BONDING

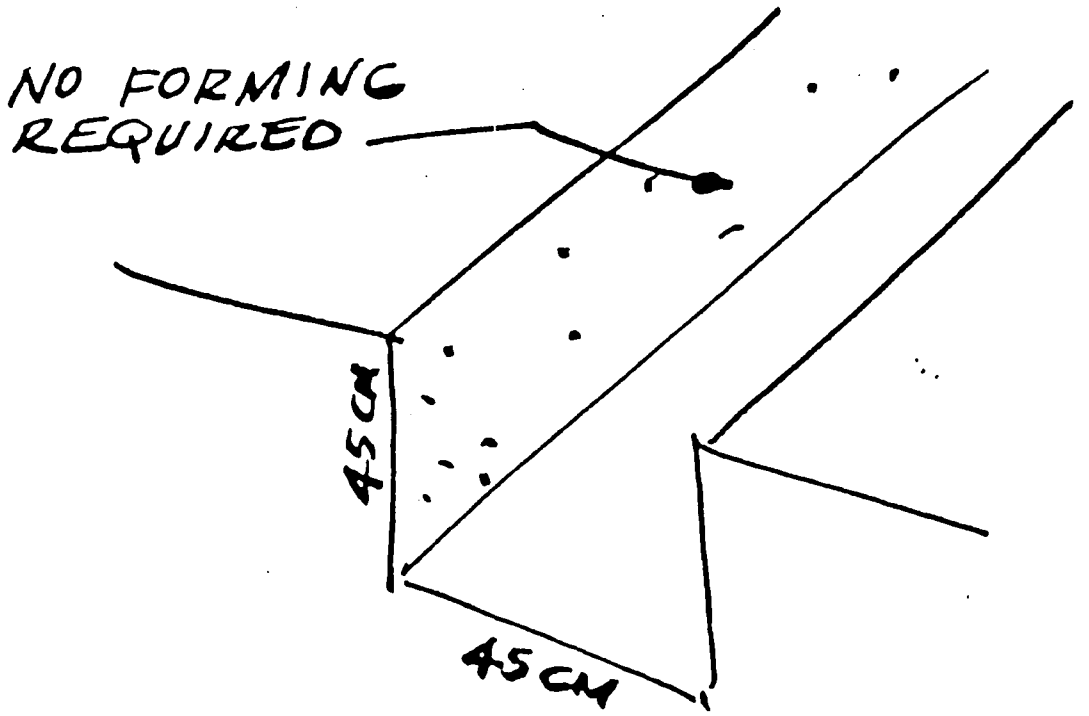
SOIL CEMENT BLOCKS



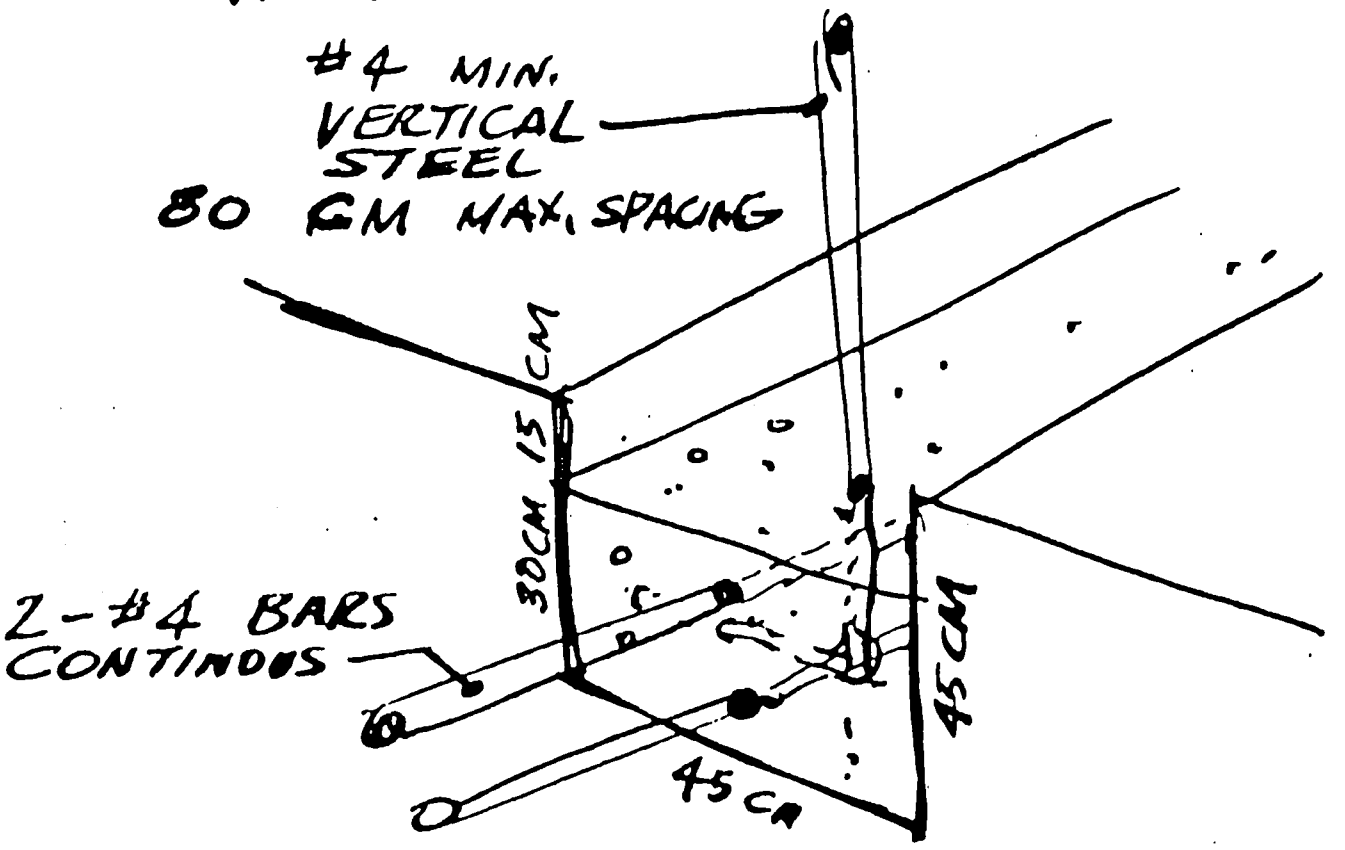
NOTES

1. EXTRA VERTICAL STEEL REQUIRE IN SOIL CEMENT MASONRY
2. SOIL CEMENT MORTAR JOINT MUST BE WIDER
3. STACK BOND REQUIRED FOR STEEL PLACEMENT.

FOUNDATION

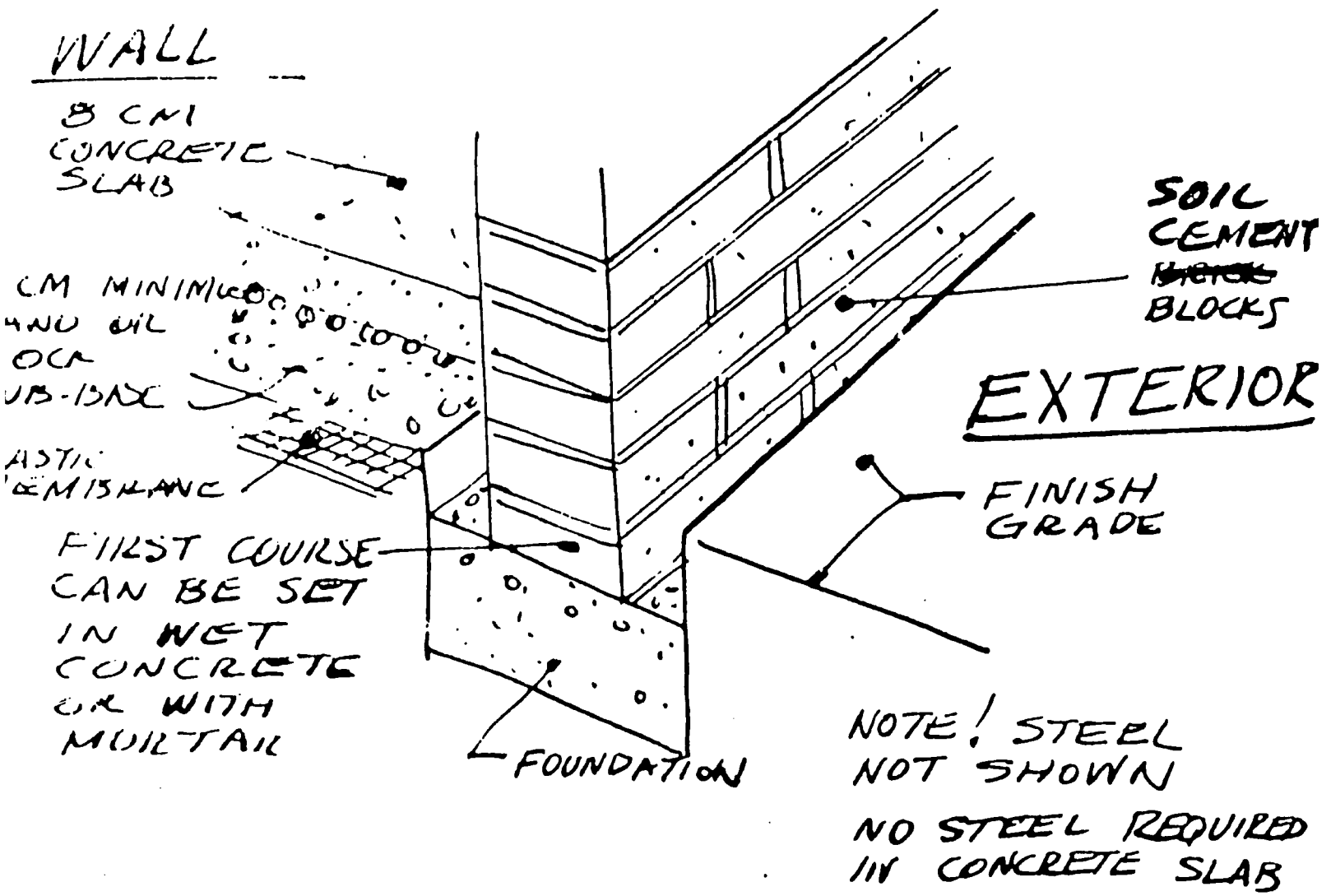


FOUNDATION TRENCH — 1 STOREY BUILDING SECTION

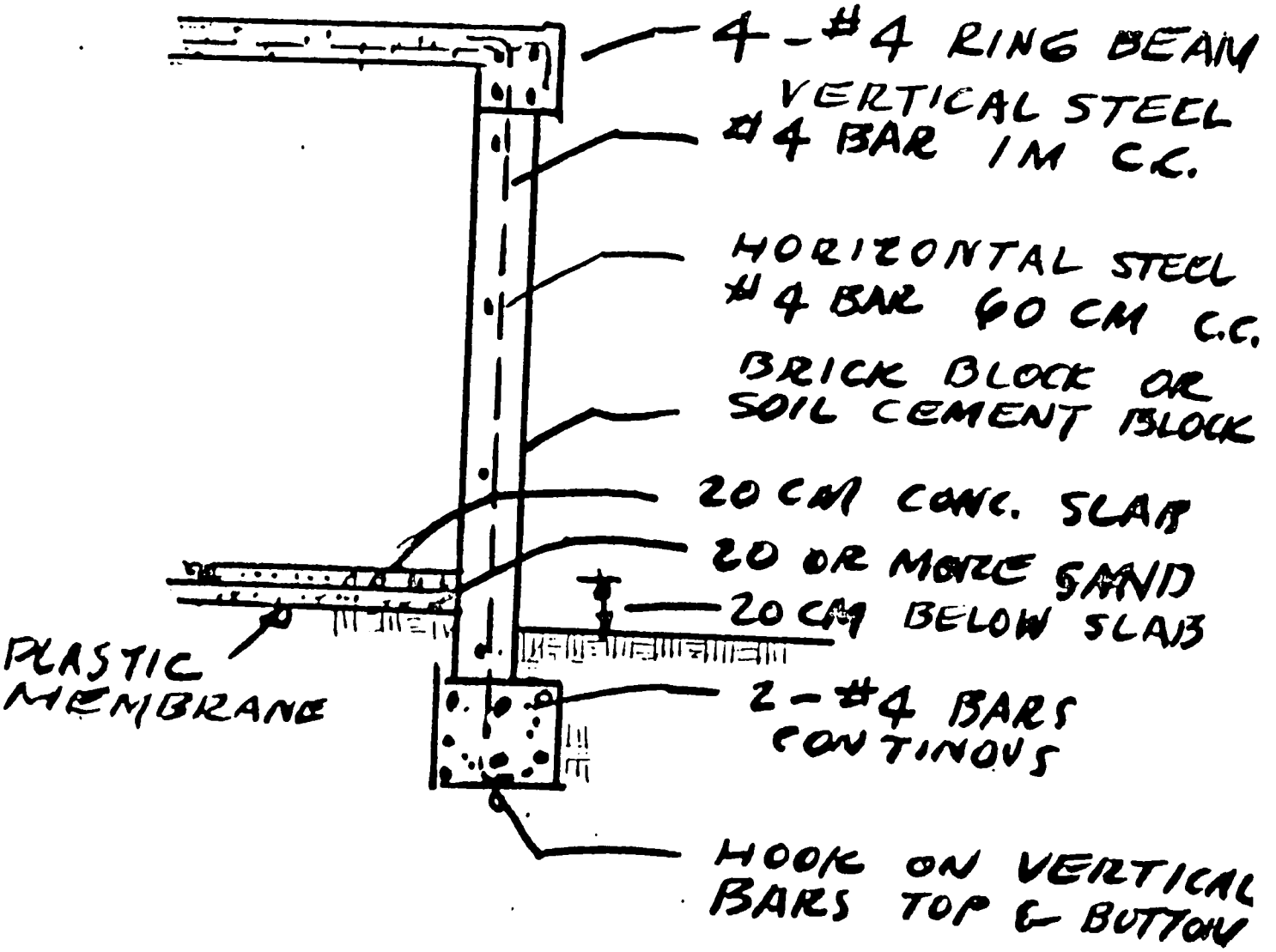


CONCRETE FOUNDATION_ 1 STOREY BUILDING SECTION

WALL AND FOUNDATION

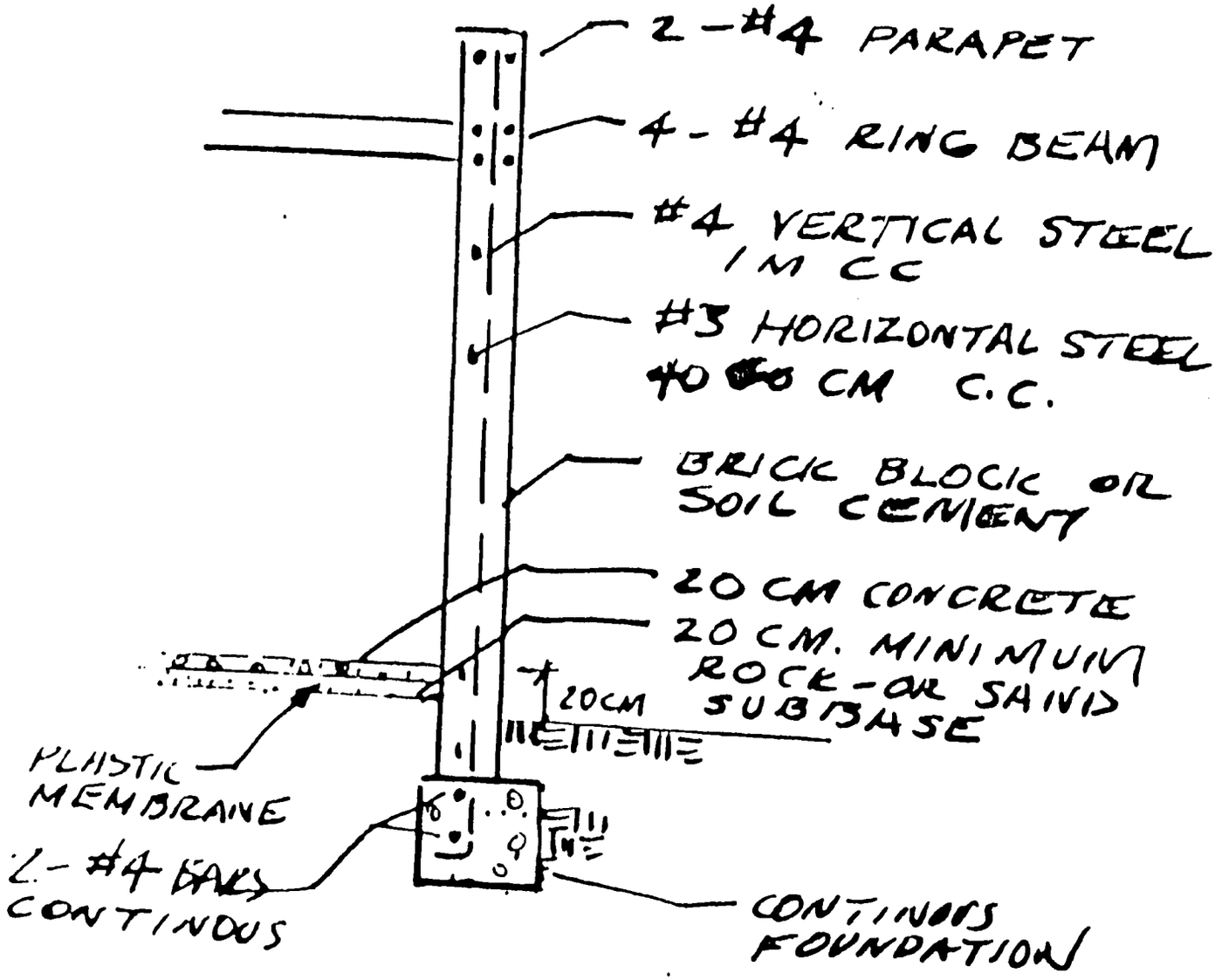


WALL SECTION



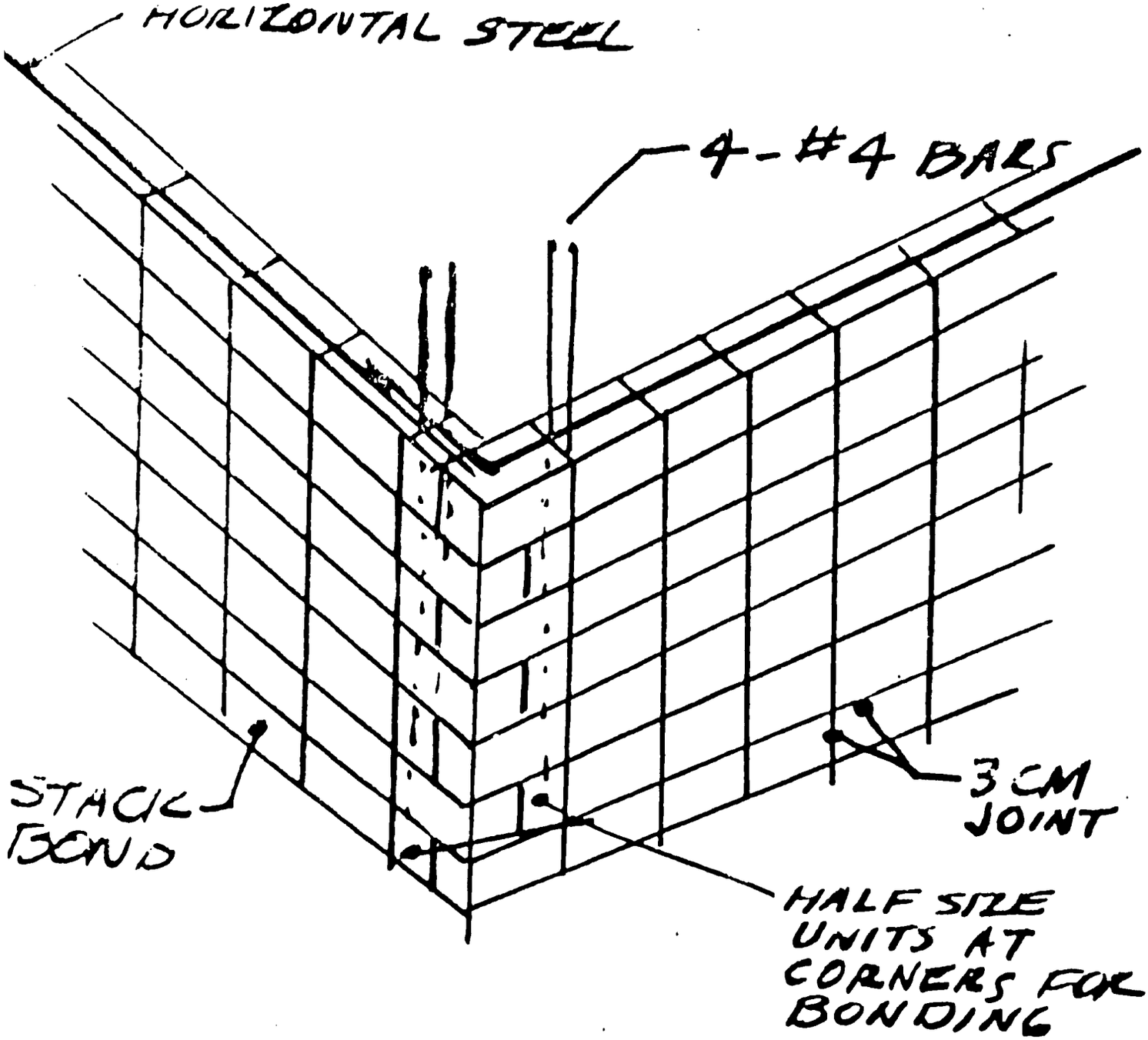
WALL SECTION

PARAPET WALL

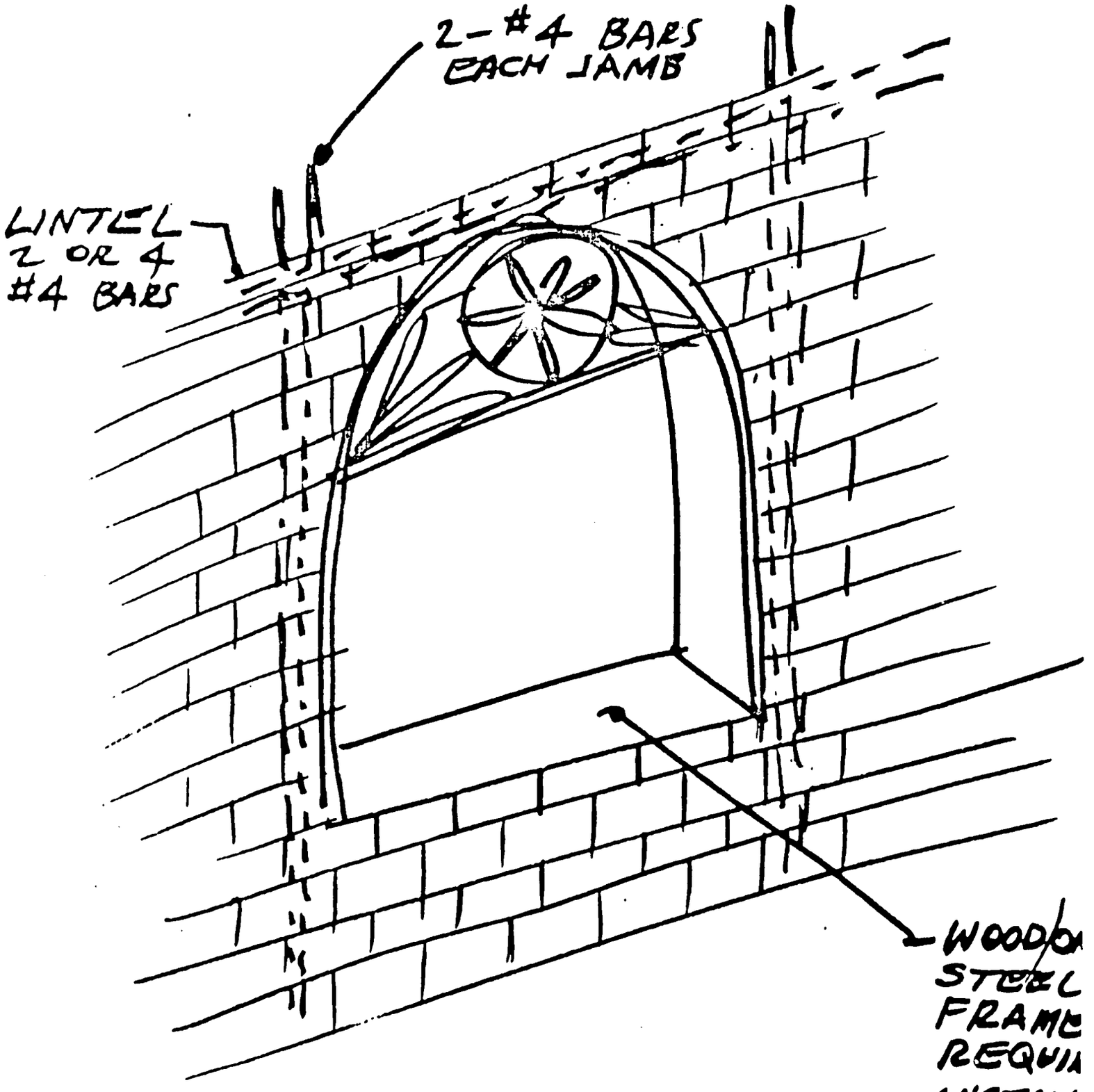


WALL CORNER

SOIL CEMENT BLOCKS



WINDOW DETAILS



IN THIS SYSTEM, WINDOW FRAME ACTS AS FORM

YEMEN ARAB REPUBLIC

SUPREME COUNCIL
FOR RECONSTRUCTION OF
EARTHQUAKE AFFECTED AREAS

EARTHQUAKE

DAMAGE

SURVEY

AGUIRRE ASSOCIATES, INC.

UNITED STATES OF AMERICA
AGENCY FOR INTERNATIONAL
DEVELOPMENT

SANA'A, YEMEN

I. FORWARD

1. The urgent task facing the government of Y.A.R. is the housing of the population in the Dhamar Province affected by the December 12, 1982 earthquake.

2. The earthquake, with a force of 5.9 on the Richter Scale, killed 1,600 people and injured 1,400 others.

3. The government estimated that 42,000 homes were damaged, of which 17,000 homes were totally destroyed. In addition, community facilities, schools and mosques were damaged.

4. The government concludes that 14,000 of the damaged houses can be quickly occupied with a structural examination and minor repairing.

II. WORK ACTION PROGRAM

1. USAID is proposing as the first task of a disaster work action program, a survey of the building damage in the Dhamar Province.

2. Damage survey task

   A. Damage survey

      a. house-by-house survey

      b. building identification

      c. building numbering

d. aerial mapping

e. site plans

f. survey forms

3. Damage Assessment

a. survey forms

(1) building number

(2) site location

(3) percent of damage

(4) major defects

(5) estimated cost

(6) cost effectiveness

(7) damage index

(8) action approval

4. Damage Summary

a. village or neighborhood

b. regional

5. Damage Evaluation

a. national goals

b. program requirements

c. cost studies

d. feasibility study

e. budget constraints

6. Structural Corrections

a. Prototype details

(1) simple "do-it-yourself details" for homeowner

(2) simple contractor details for owner financed work

(3) major damage rehabilitation detail requiring government assistance

III. SURVEY TEAM

1. Personnel

Team Leader: Architect

Surveyors: Associate level architects and engineers Yemeni and American

2. Time Frame

a. Survey requirements

(1) 27,000 houses

(2) survey time: 30 minutes per house

(3) total survey 340 man-weeks (40 hours = man week)

(4) eight man team = 5 mos.

(5) administrative time = 1 month

(6) program summary and report = 2 weeks

IV. PUBLIC RELATIONS

Program Promotion Activities

1. Mass media

a. Television

b. Film Strips

c. Slide Shows

d. Radio

e. Newspapers

2. Official Activities

a. Local information and technical assistance officers

b. Visits by local and national leaders

3. Local level activities

a. Selection of local (village) leader for reconstruction interface

b. "Town Hall" meetings

4. Follow-up Program

a. Monthly activities

b. National interface

SURVEY FORM

YEMEN ARAB REPUBLIC

SUPREME COUNCIL FOR RECONSTRUCTION OF EARTHQUAKE AFFECTED AREAS

SURVEY FORM

Owner-Occupant _____

Building Number _____ Site _____ Village _____

Surveyor _____ Date _____

Materials: Wall _____ Roof _____ Floor _____

Wall Damage: North _____ West _____ South _____ East _____ Other ____

Replacement Required: Doors _____ Windows _____ Roof _____ Floors _____
Plumbing ____ Electrical _____ Lighting _____ Fence _____

Estimated Cost: _____

Construction: Homeowner _____ Contractor _____ Both _____

Underway _____ % completed _____ Needs _____

Percent Damaged _____ % Damage Index: _____ Scale 1 to 5

Correction Details:

PROPOSAL

SITE PLANNING FOR 1,200 VILLAGES

DHAMAR PROVINCE (EARTHQUAKE ZONE)

WITH

COMPUTER AIDED DRAFTING SYSTEMS

FOR THE

SUPREME COUNCIL FOR THE RECONSTRUCTION OF

EARTHQUAKE AFFECTED AREAS

GOVERNMENT OF YEMEN ARAB REPUBLIC

AGUIRRE ASSOCIATES, INC.

RANCHO PALOS VERDES, CALIFORNIA

UNITED STATES OF AMERICA

AGENCY FOR INTERNATIONAL DEVELOPMENT

SANA'A, YEMEN

TABLE OF CONTENTS

I. PROGRAM REQUIREMENTS

1. The Supreme Council for the Reconstruction of Earthquake Affected Areas (SCR) is on a crash program to provide housing for 42,000 families. As part of this reconstruction program, it is necessary to locate and re-site 1,200 villages in the Dhamar Province.

2. The SCR is simultaneously designing and bidding for construction of 15,000 new housing units to be located in the new model villages.

3. As time is of the essence, the SCR is soliciting Computer Aided Drafting Systems in order to meet the YAR timetables.

4. The Engineering and Planning Office of the SCR is currently understaffed with professionally qualified personnel and will not be able to meet the presidential deadlines.

II. SCR PROCEDURES

1. The SCR is currently designing the first village site plans, using its limited facilities.

2. Mr. Munir Kaid A Taher, the Manager of Engineering, estimates that the current staff of 14 should be expanded to at least 40 professionally trained architects and engineers in order to succeed. However, there are no professionally trained people in Yemen available. The current staff of 14 is mainly expatriates.

3. The current output of site plans is one village, utilizing 80 man-hours.

4. Based on the existing SCR procedures, the US/AID consultant has suggested the use of Computer Aided Drafting Systems (CAD) as the only method to meet the presidential deadlines.

III. COMPUTER AIDED DRAFTING SYSTEMS

1. The use of CAD wuld produce one village plan in less than two man-hours.

2. The CAD will provide the following architectural and engineering parameters:

   A. Site Planning

   B. Local site problems

   C. Local customs-traditions

   D. Geological restraints

   E. Topography

   F. Number of dwellings per village

   G. Size of village center

   H. Number of satellite village units

   I. Street Design

   J. Infrastructure requirements

   K. Public utilities, i.e. water, sanitation, etc.

IV. COST ESTIMATE

1. A preliminary cost estimate for planning purposes is provided by John Aguirre, A.I.A., the US/AID consultant. This estimate does not imply that Aguirre Associates, Inc. is soliciting the proposed project.

2. Cost Estimate:

A.	CAD System and Software	$ 85,000*
B.	Architectural Computer Consultant (1 month)	$ 15,000
C.	Administrative costs	$ 5,000*
D.	Burden rate 150%	$ 52,500
E.	Profit 10%	$ 15,750
	TOTAL	$157,500

*These costs should be refined when CAD system is selected and adjusted to actual costs.

JOHN AGUIRRE, A.I.A.
Architect-Urban Planner

June 2, 1983

YEMEN ARAB REPUBLIC

Supreme Council for Reconstruction of
Earthquake Affected Areas

Executive Office: P.O. Box 17077 - Sana'a

Prequalification Questionnarie for Contractors

For the construction of 15,000 residential units, Phase I, Dhamar Province.

I. The Executive Office invites competent contractors to secure Prequalification Questionnarie from this office at:

HADDA CENTRE

Building No. 5; 5th Floor

Hadda Road, near Hadda Cinema

P. O. Box 17077 Sana'a

Telephones: 215624, 215625, 202050 and 202052, Sana'a, YAR

Beginning on Saturday, 16th July 1983, the Prequalification Questionnaire shall be answered completely and returned to this office not later than Sunday, 31st July 1983, together with the following documents:

a. Company Brochure

b. Brief summary of completed building projects by your company.

c. Any additional pertinent information on building systems and construction methods developed by your company.

II. All who have previously submitted information on their company shall contact the Executive Office to obtain the Prequalification Questionnaire. It shall be completed with all the information required.

III. All Contractors who cannot answer the Prequalifications Questionnaire and produce the required information and documents will not be considered. Therefore, they will be disqualified for this project.