Support Action for Strengthening PAlestine capabilities for seismic Risk Mitigation SASPARM 2.0

Deliverable D.B.1

Report on the structural typologies identified during the field investigation

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Project co-funded by ECHO - Humanitarian Aid and Civil Protection

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1 INTRODUCTION

The seismic behavior of the structural systems of buildings greatly influences seismic losses. The majority of deaths and injuries in earthquakes occur because of the disintegration and collapse of buildings, and most of the economic loss and social disruption caused by earthquakes is also attributable to the failure of buildings.
Studies of earthquakes damages show that some types of construction tend to be more vulnerable than others. The structural and architectural configuration of building is one of the main determinants of its vulnerability. For instance, a building with unreinforced masonry walls can be expected to be more vulnerable than other types.
The definition of a building typology catalogue is the first step for large scale vulnerability assessment. Once the building types have been identified the seismic vulnerability of each type is assessed.
The building types that characterize the as built in Nablus are:

- Reinforce concrete frame buildings;
- Shear wall buildings;
- Masonry Buildings;
- Buildings with soft storey.

More details about these typologies are given in the following chapter of the current document.

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2 REINFORCED CONCRETE FRAME BUILDINGS

This type of buildings is the most common in Nablus. It mainly consists of in-situ casted reinforce concrete slabs supported by reinforced concrete beams and columns. This type is mostly used for residential buildings with 2 to 3 bays in both directions and up to the heights of 15 floors. Generally it is common to use for these buildings ordinary concrete of cylindrical compressive strength between 24 and 32 MPa. The reinforcing steel can be of tensile strength 420 MPa. The partitions are generally made of hollow concrete blocks with 100 mm thickness. The exterior walls in these buildings are made of:

- Masonry walls made of three layers, namely: hollow concrete blocks of 100 mm thickness, weak concrete layer of about 130 mm thickness, and stone layer of about 70 mm thickness. Figure 2.1 shows a cross section of this type of exterior walls. The range of weight for external walls including cladding varies between 6 to 7 KN/m^2.
- Hollow concrete blocks with thickness of 150 to 200 mm. The range of weight for external walls varies between 2 to 2.5 KN/m^2.

Figure 2.1: Cross Section of Exterior Masonry Wall

The type of slabs have an influence also on the buildings geometrical dimensions (slab span, interstory height). The two used typologies of slabs are listed below.

- **Ribbed slabs with hidden beams:** In this category, the slabs are typically designed and fabricated as either one-way or two-way ribber slabs by proper arrangement of hollow concrete blocks. Each hollow block has 400 mm length, 200 mm width and thickness in the range of 140 mm to 320 mm. Figure 2.2 and Figure 2.3 show details of both systems. Typical depths of such slabs vary from 200 to 500 mm. The rib width is generally in the range of 100 to 200 mm. The weight of one way slabs is in the range of 4 to 7 kN/m^2 while that of two way slabs ranges between 5 and 8 kN/m^2. This is in addition to a super imposed dead load in the range of 3 to 4 kN/m^2.The beams are usually made hidden within the thickness of the slab. Typically, interstorey height range between 3.0 to 3.5 m, and width of the bays range from 4 to 6 meters in both directions. Generally, in this building system, minimum reinforcements for the RC columns and slabs are used (around 1% of steel for columns and 0.35% for the slabs). The beams used in this system may provide framing action in both directions, especially for the two-way ribbed slabs.

Figure 2.2: One way ribbed slab system

Figure 2.3: Two way ribbed slab system

- **Solid slabs with drop beams:** In this kind of buildings, the slabs are made solid of typical thickness ranging from 150 to 300 mm supported on drop beams. The weight of the slab range between 3 and 6 kN/m^2. This is in addition to a super imposed dead load in the range of 3 to 4 kN/m^2. Depth of the beams may range from 400 to 800 mm. Such high depth of the beams allows for large spans for the slab panels, ranging from 6 to 8 m in both directions. The height of the floors may be between 2.8 and 5 m. The slabs of this system can be made either one-way or two-way depending on the allowable spans. This kind of buildings is mainly used for car parking garages and commercial buildings.

More details about the reinforced concrete frame buildings and its construction processes are given in Appendix 1.1 and Appendix 2.1.

3 SHEAR WALL BUILDING

This kind of buildings is gaining more favor in Nablus and is becoming more common.

Typically such buildings range from 5 to 20 floors in height and accommodate 3 to 5 bays in each direction. Reinforced concrete walls of typical thickness of 250-300 mm are used to provide lateral and vertical support for the building. The building may also include interior reinforced concrete columns which participate in carrying the gravity loads but their participation in carrying the lateral load is small and negligible. Appendix 2.2 shows a plan of a building containing shear wall system. The walls can be cladded with masonry stones thus giving the appearance of a masonry building as shown in Figure 3.1.

The range of weight for external walls including cladding stones varies between 8 to 10 kN/m^2 The total weight consists of slab weight in the range of 4 to 7 kN/m^2 and super imposed dead load of about 3 to 4 kN/m^2.

Figure 3.1: Stone Cladding of Shear Wall Building

More details about the shear wall buildings and the construction processes of stone cladding are given in Appendix 1.2 and Appendix 2.2.

4 MASONRY BUILDINGS

Masonry buildings used to be common in Nablus up to the1970. Masonry buildings comprise masonry walls that support reinforced concrete slabs. The masonry stones used in this kind of construction come in typical blocks of 250 mm height, 300-600 mm width and 150-200 mm thickness and are generally placed row-by-row to form the wall. Unreinforced concrete of generally low compressive strength (with compressive strength of 15 to 20 MPa) and of thickness of 100-200 mm is then cast in between to provide cohesion the the the two walls in blocks. The masonry wall would then be used to support the concrete slabs. Buildings of this type are generally 1 or 2 bays in both directions with 2-3 floors in height. Different combinations exist depending on the type of walls and slabs used.

As for the walls, two categories exist depending the method of construction (see Appendix 2.3). In one type, the concrete is sandwiches between two surface layers of masonry stones, thus resulting in a wall thickness around 400-500 mm. In another type, the masonry stones are installed row-by-row and then concrete is cast behind them via suitable framework, resulting in a wall with one-side masonry stones and the other side concrete surface Such walls can gross in thickness up to 350 mm. Typically the cross sectional area of walls is about 10 to 30% from the floor area. This high ratio is mainly because masonry walls have large thickness of around 400-500 mm as discussed above.

There are not data on the shear resistance of composite wall. Hence, the shear resistance of the block walls is considered and due to the poor construction standards the resistance of hollow blocks with high percentage of voids is assumed. Such resistance ranges between 40 kN/m^2 to 100 kN/m^2.

When it comes to slabs, two kinds of slab construction are used (see Appendix 2.3). One type is two-way solid slabs with typical thickness around 200-250 mm. The second type is using steel joists as supporting beams for the solid slabs, thus resulting in composite steel-concrete construction for the slabs. The slabs in the composite floor construction is generally thinner (100-120 mm) with simple reinforcement. While in the first type slab spans might range from 4-5 meters, in the second type spans may range between 5-7 m in both directions.

The weight of the slab and the superimposed dead load comprise about 5 to 10 kN/m^2. The unit weight of masonry wall is about 25 kN/m^3.

Figure 4.1, Figure 4.2 and Figure 4.3 show pictures of masonry wall buildings.


Figure 4.1: A Three Story Masonry Building


Figure 4.2: An Old Masonry Building


Figure 4.3: A Masonry Building with the Last Story Walls Made of Hollow Concrete Blocks

More details about the Masonry Buildings are given Appendix 1.3 and Appendix 2.3.

5 BUILDING WITH SOFT STORY

This type of buildings comprises one of the shear wall system or the RC frame system but with a soft story due to missing infill walls every ware or in part of the floor. The stiffness of the soft story is significantly smaller than the stiffness of other stories and irregular plan distribution of infill walls causes also eccentricity that further compromise the structural performance. Figure 5.1and Figure 5.2 show partial and full soft stories in RC frame buildings.

Figure 5.1: A Building with Partial Soft Story

Figure 5.2: A Building with Full Soft Story

6 APPENDIX 1: SELECTED PHOTOS AND DETAILS

Appendix 1.1: R.C. Frame buildings (Ribbed Slabs with hidden beams)
Appendix 1.2: Shear wall buildings with stone cladding
Appendix 1.3: Masonry building

6.1 Appendix 1.1

Figure 6.1: Typical R.C. Frame Buildings in Nablus, Palestine

Figure 6.2: Two Multistory R.C. Frame Buildings in Palestine

Figure 6.3: Steel Cage for a Concrete Column in an R.C. Frame Building

Figure 6.4: Formwork for a Concrete Column in an R.C. Frame Building

Figure 6.5: Concrete Columns in an R.C. Frame Building

Figure 6.6: Circular Concrete Columns in an R.C. Frame Building


Figure 6.7:Reinforcement Cage for Concrete Beams in an R.C. Frame Building

6.2 Appendix 1.2


Figure 6.8: Shear Wall Building with Stone Cladding

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Figure 6.9: Reinforcement Used to Fasten the Stone Cladding to the Shear Wall

Figure 6.10: Application of Stone Cladding to a Shear Wall Building

Figure 6.11: Typical Method for Fastening Stone Cladding to a Shear Wall Building

Figure 6.12: Side Ties for Fastening Stone Cladding to a Shear Wall Building

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6.3 Appendix 1.3

Figure 6.13: A Two Story Masonry Building

Figure 6.14: A Three Story Masonry Building

Figure 6.15: A Four Story Masonry Building

7 APPENDIX 2: PLANS AND DETAILS

Appendix 2.1: R. C Frame buildings (Ribbed Slabs with hidden beams)
Appendix 2.2: Shear wall buildings with stone cladding
Appendix 2.3: Masonry building

7.1 Appendix 2.1

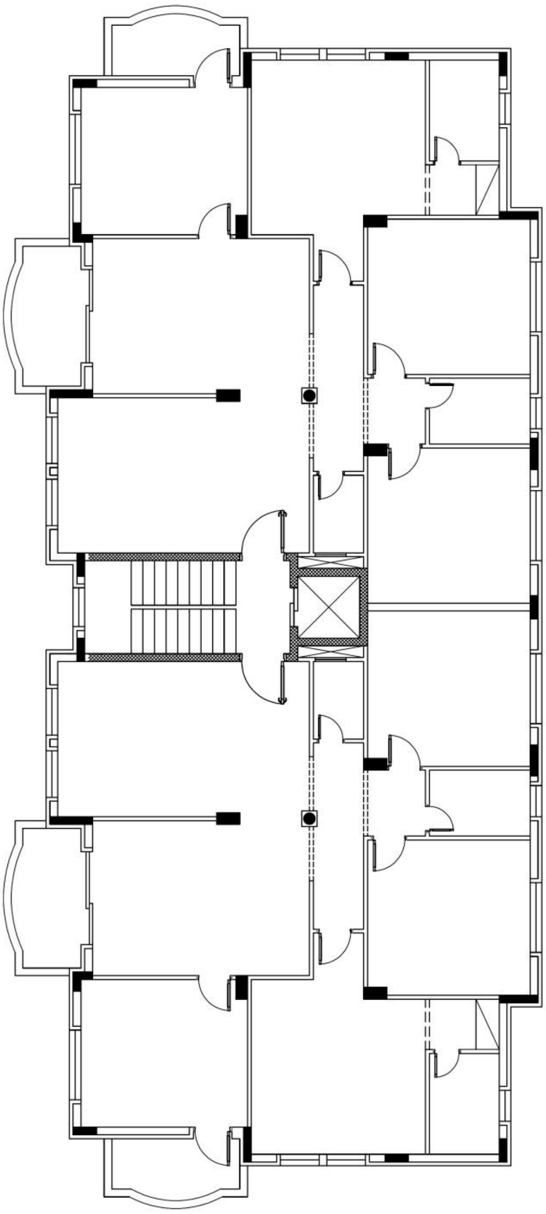


Figure 7.1: Typical Architectural Plan for a Frame Concrete Building

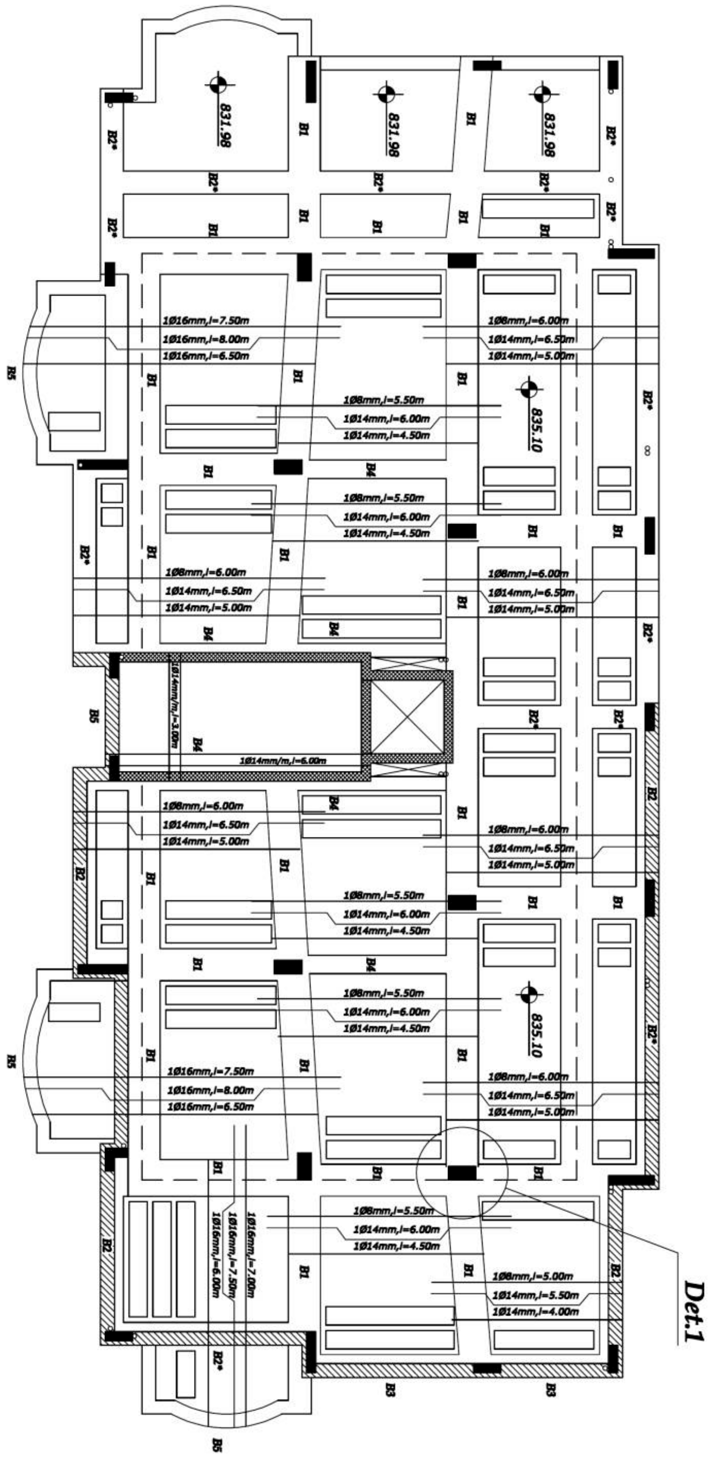


Figure 7.2: Typical Slab Reinforcement for a Frame Concrete Building

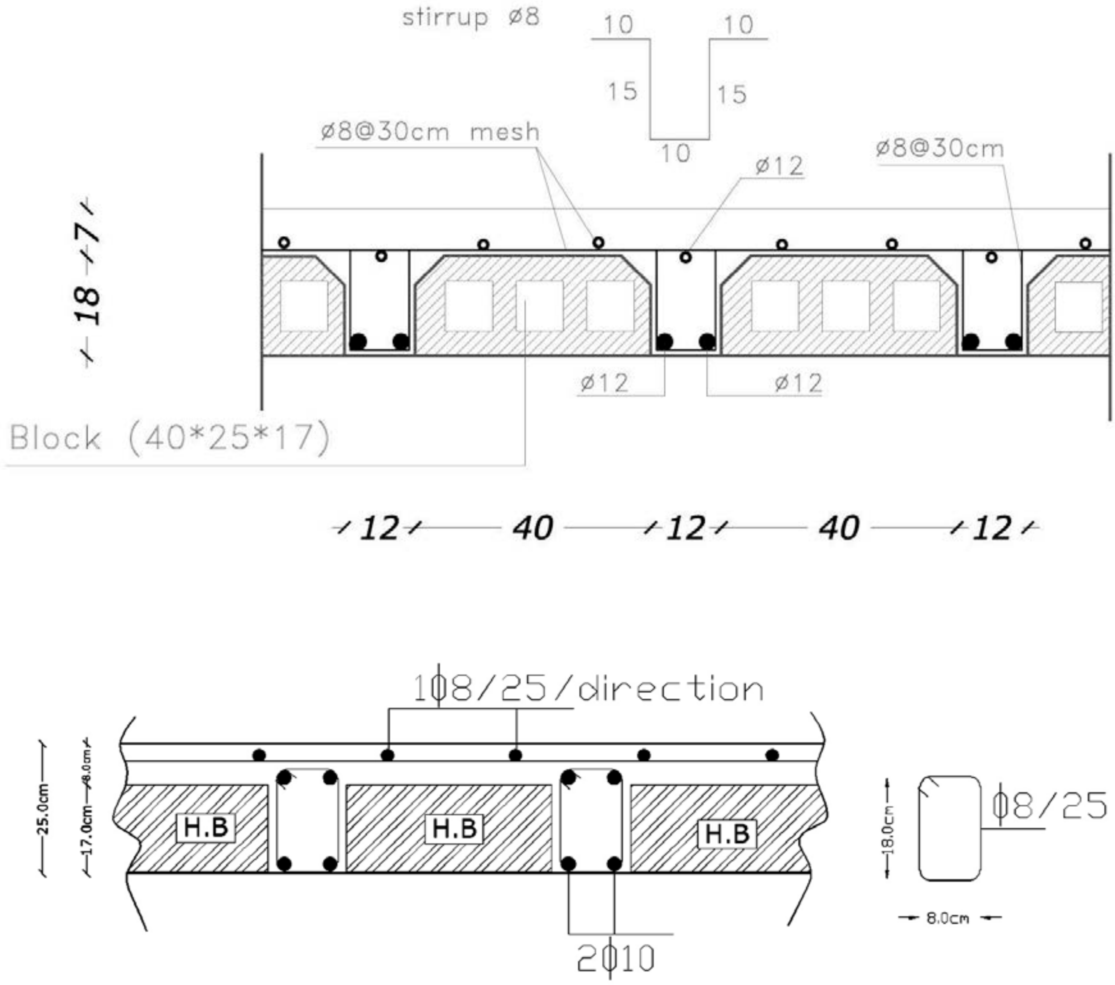


Figure 7.3: Typical Ribbed Slab Cross Section

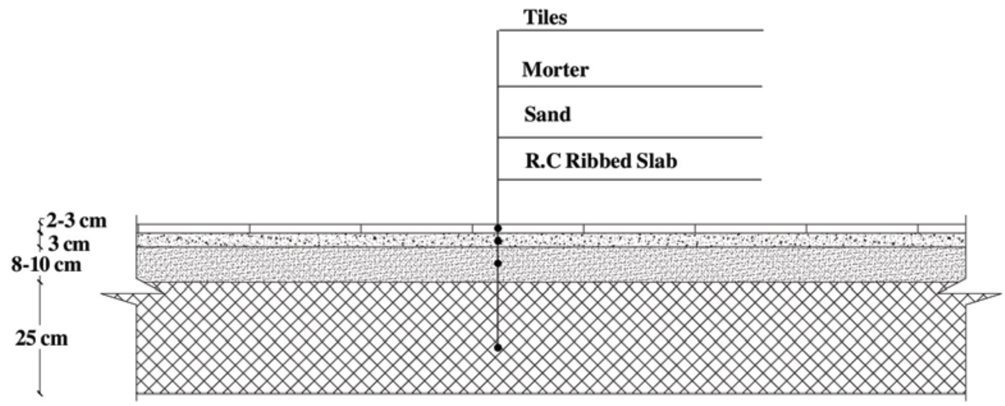


Figure 7.4: Typical Architectural Floor Section

7.2 Appendix 2.2

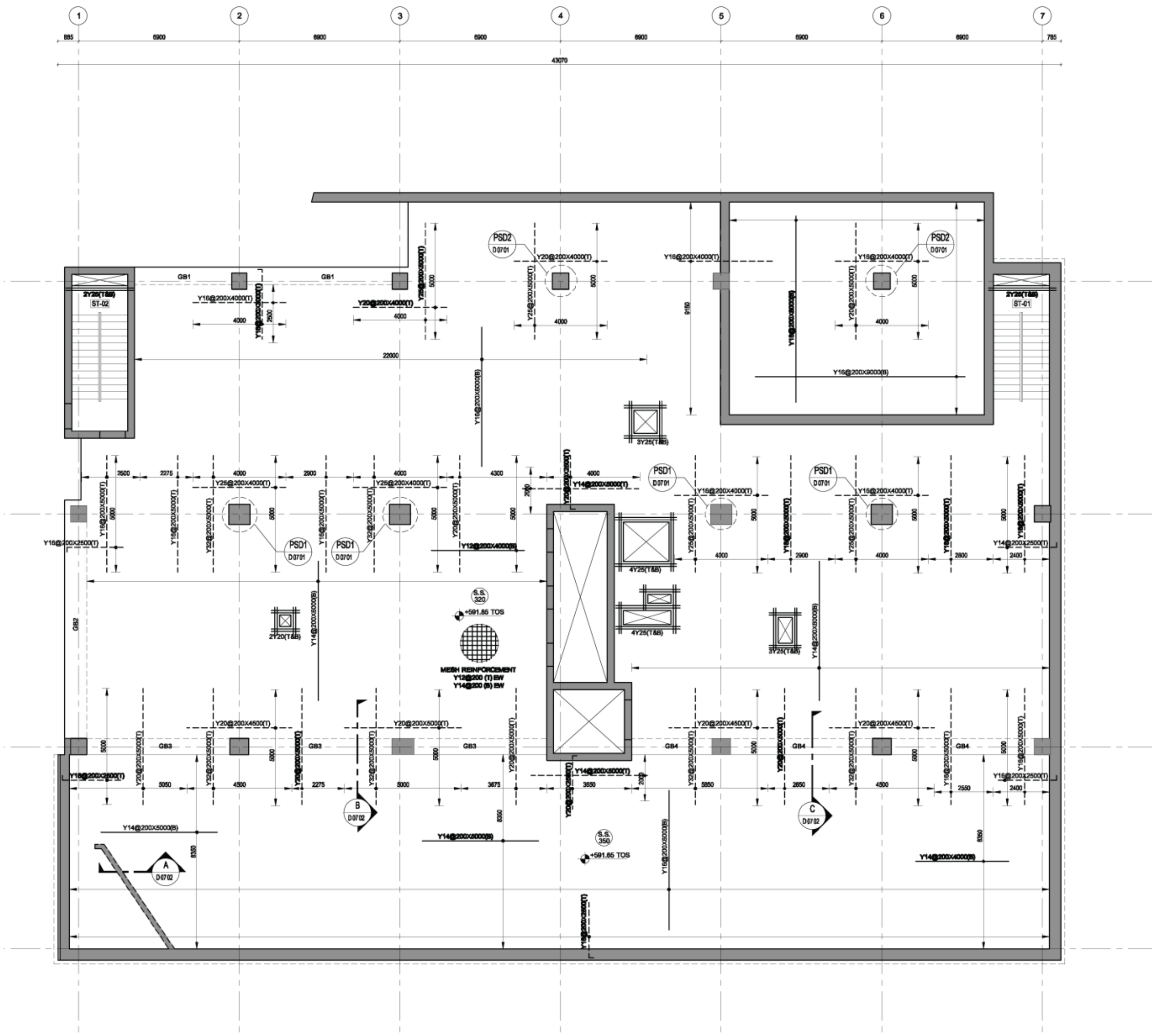


Figure 7.5: Plan for a Shear Wall Building with Stone Cladding

7.3 Appendix 2.3

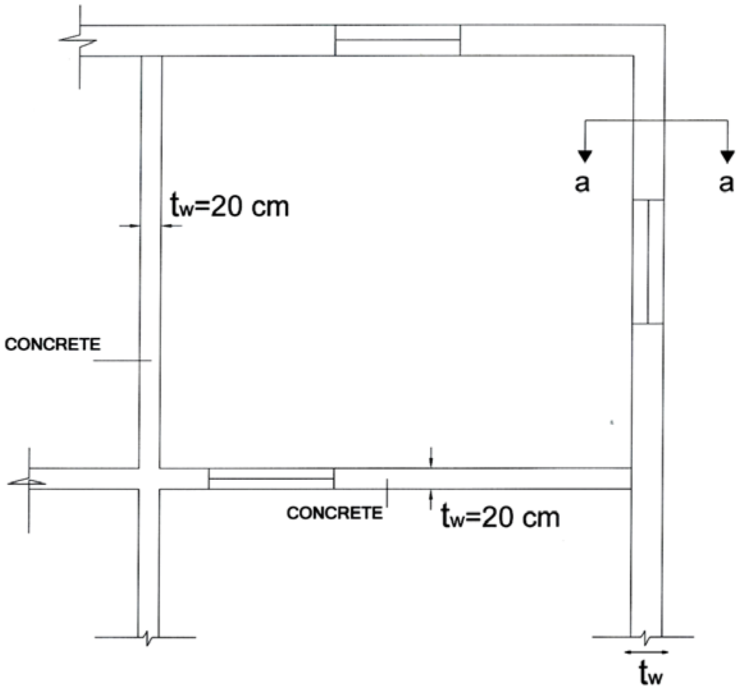
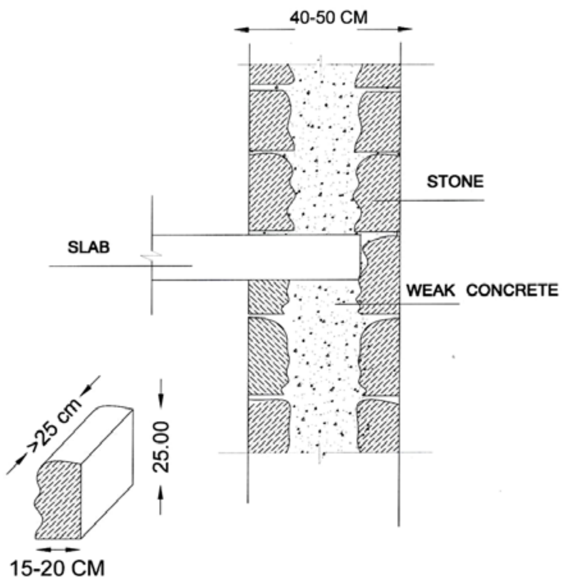


Figure 7.6: Plan for a Masonry Building



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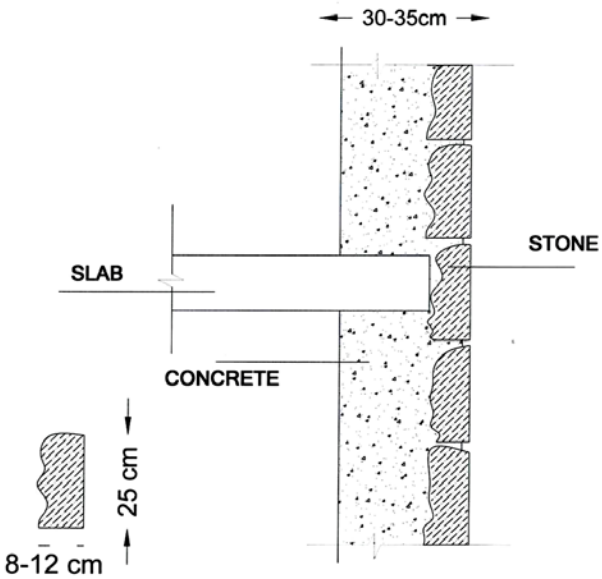

Section a-a

Figure 7.7: Detailing of Section a-a in Figure 7.6

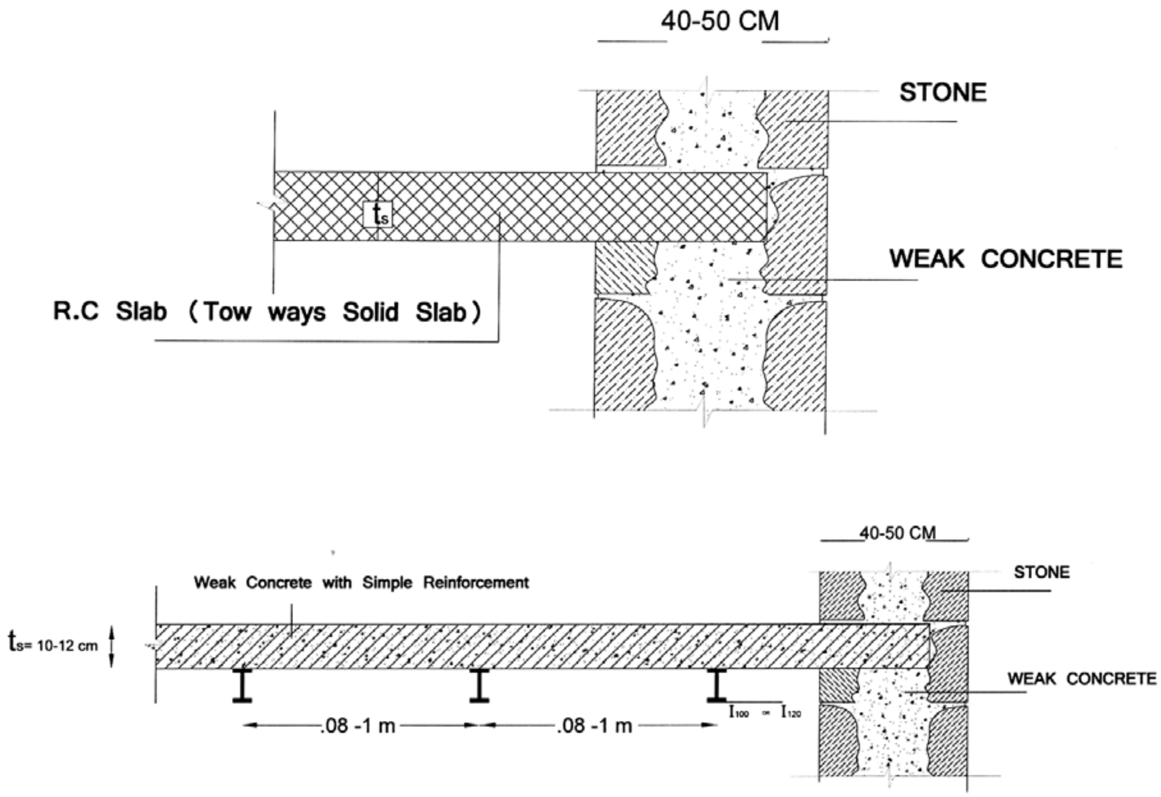

Figure 7.8: Concrete Slab in Masonry Buildings