

### 10-3-2 Masonry Buildings

#### (1) Retrofit Methods for Normal Masonry Buildings in Algiers

Approximately 34% of all buildings in the study area are masonry structures. Approximately 43% of the masonry is simple stone, 45% is un-reinforced masonry stone with a composite slab, and 12% is un-reinforced brick masonry. Many masonry buildings are very old, for example, masonry buildings in Algiers Center were constructed over a range of approximately 60 years from 1880 to 1940. And 48% of masonry buildings are more than two stories, especially un-reinforced stone masonry buildings.

These masonry buildings have some structural or cultural concerns as follows;

- Rigid but brittle structures: Vulnerable to earthquake.
- Old buildings: Degradation of material, weak wall to wall connections and/or wall to floor.
- Over loaded buildings: Additional stories have been added to original structure (due to increased family members etc.).
- Traditional façades: People want to keep the original façade to preserve cultural heritage.

To address the above conditions, we recommend seismic retrofit methods for stone and brick masonry buildings as shown in Table 10-20.

Table 10-20 Recommended Retrofit Methods for Masonry Buildings

Condition	Objective	Applicable Seismic Retrofit Methods
Vulnerable Structures	Add mainly strength and ductility	<ul style="list-style-type: none"> <li>• Adding RC shear walls</li> <li>• Cover with RC jacketing wall (for dwelling houses)</li> <li>• Adding masonry wall: increasing thickness, infilling openings, buttress</li> <li>• Provide new frame: RC structure or Steel structure</li> </ul>
Old Buildings	Add strength and ductility, and replace degraded material	<ul style="list-style-type: none"> <li>• Replace excessively rigid diaphragm floor and roof systems</li> <li>• Connect wall to wall and wall to floor</li> <li>• Provide new frame: RC structure or Steel structure</li> <li>• Demolish and rebuild a suitable structure</li> </ul>
Over Loaded Buildings	Reduction of over load	<ul style="list-style-type: none"> <li>• Demolish the over loaded stories</li> <li>• Demolish and build a suitable structure</li> </ul>
Traditional Façades	Make effort to preserve façade	<ul style="list-style-type: none"> <li>• Preserve façade and provide suitable structure</li> <li>• Adopt a seismic isolation system</li> </ul>

The above retrofit techniques and details, except the seismic isolation system, are conventional methods currently in use in Algiers.

(2) Recommendations for Retrofit Methods for the Presidential PALACE (herein after Le PALAIS)

According to our seismic evaluation (Refer to Chapter 9-1-1), le PALAIS required certain seismic retrofit work as soon as possible. However, since this seismic evaluation was performed based on an “assumed shear strength of the bearing wall unit of 0.056 Mpa (N/mm<sup>2</sup>)”, the actual shear strength of the joint material in the existing bearing wall unit should be confirmed before final design.

1) Recommendations for a Seismic Retrofit Plan

Le PALAIS was constructed with beautiful traditional and historical designs on the exterior and interior façades throughout the building. A basic requirement for the seismic retrofit plan is that it has to preserve this beauty. Therefore, we can not apply any additional strengthening materials, such as concrete shear walls or steel supports to the outside of existing bearing walls or supports. Under this condition, three types of retrofit plans for the main structure and a reinforcing plan for the arch and roof system at the main hall of new Palace are recommend as follows;

(A) Adoption of a Seismic Isolation System at the Under-ground Level

The seismic isolators with dampers are provided at the under-ground level, along with approx. 50 cm to 60 cm of clearance space around the building’s footprint area for building movement during a large earthquake. Since the main hall block area has a basement floor, the seismic isolators can be set in the upper-part of the basement bearing wall or under the basement floor level. The proposed layout of the isolators is shown in Figure 10-4 to Figure 10-6.

In general, when a seismic isolation system is provided for a building, the seismic force response will be reduced by between one third and one fifth. Even if a base isolation system is provided for the entire superstructure, the possible need for strengthening the superstructure on each floor level must be investigated to ensure the safety of building. According to our seismic evaluation, it is possible that only the 1st and 2nd floors of both blocks of the New Palace require strengthening.

Since the construction work, including installation of the seismic isolators is very sensitive, instruction from a special supervisor will be necessary.

The cost of this retrofitting work is quite high (in Japan, it is approximately 40% to 80% of replacement cost). However, for this building, it is a quite useful method.

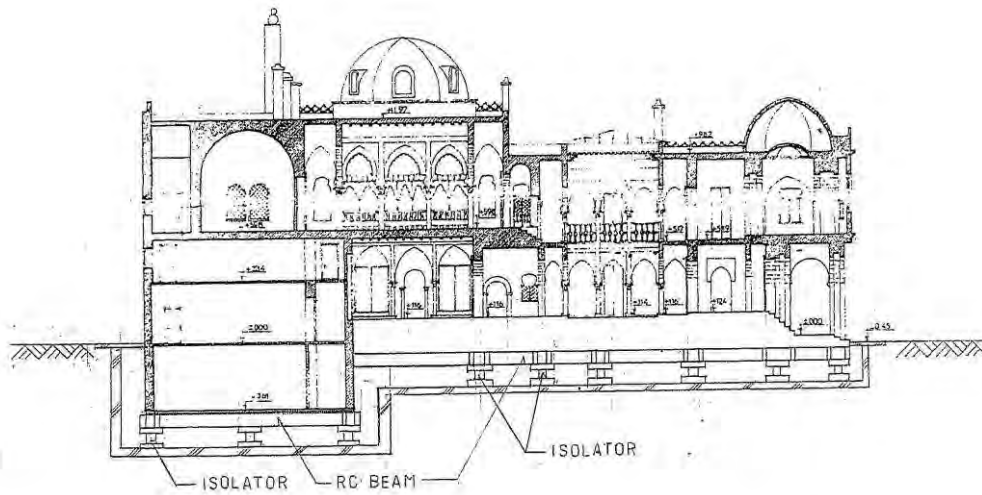


Figure 10-4 Elevation showing Installation of Seismic Isolators

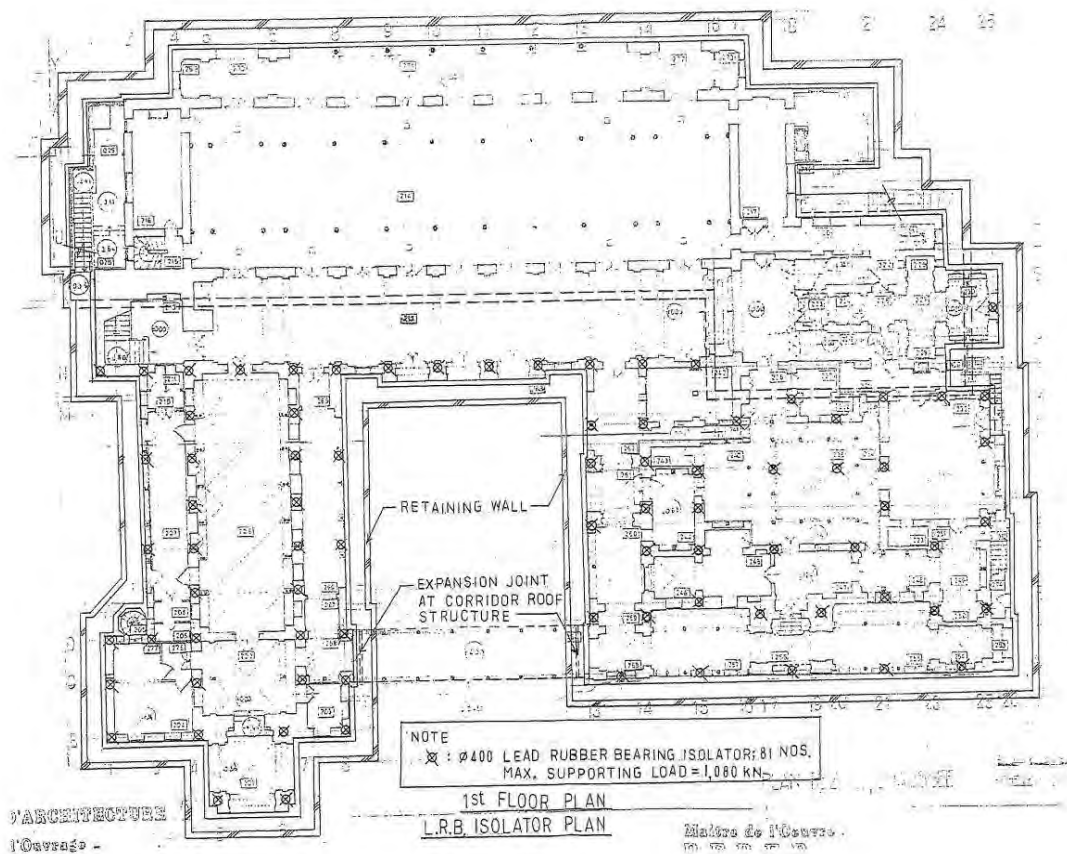


Figure 10-5 Lead Rubber Bearing Isolator Plan (Below 1st Floor Level)

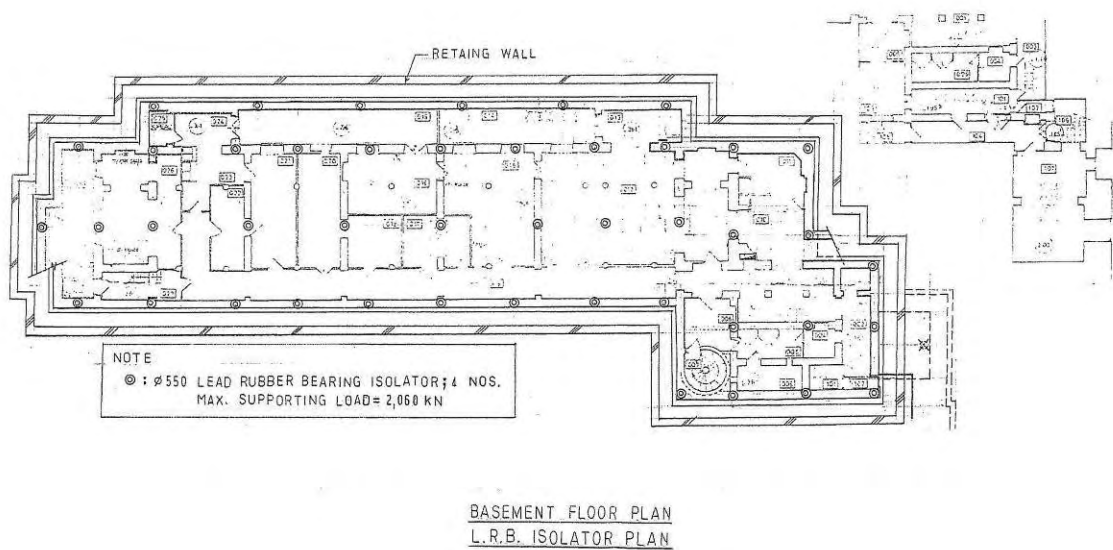


Figure 10-6 Lead Rubber Bearing Isolator Plan (Below Basement Floor Level)

(B) Adoption of Flat Roof and Reinforcement for Existing Steel Arch

The existing arches in the main hall were reinforced with steel arch trusses. Those are presently supported by marble columns (approx. 3.0 meter height) with pin joints. However, there is no space to provide additional shear walls or horizontal supports.

The roof material for the Main Hall is corrugated asbestos-cement sheet. Asbestos is now known to be harmful to human health, and it will need to be removed as soon as possible. The asbestos sheet itself is not harmful. However, it becomes harmful scattered microscopic asbestos-fibers during removing or maintenance work.

Therefore, the sloped asbestos roof will be changed to the flat roof made of light material such as metal sheet, and new steel truss beams will be added at the same level as the existing steel truss beams. These steel truss beams will make a rigid diaphragm with the horizontal steel bracings. The additional steel trusses will be connected to the existing steel arches for vertical strength. This structural work will be executed with sufficient care so as not to cause a fire during the welding work. The strengthening plan is shown in Figure 10-7 and Figure 10-8.

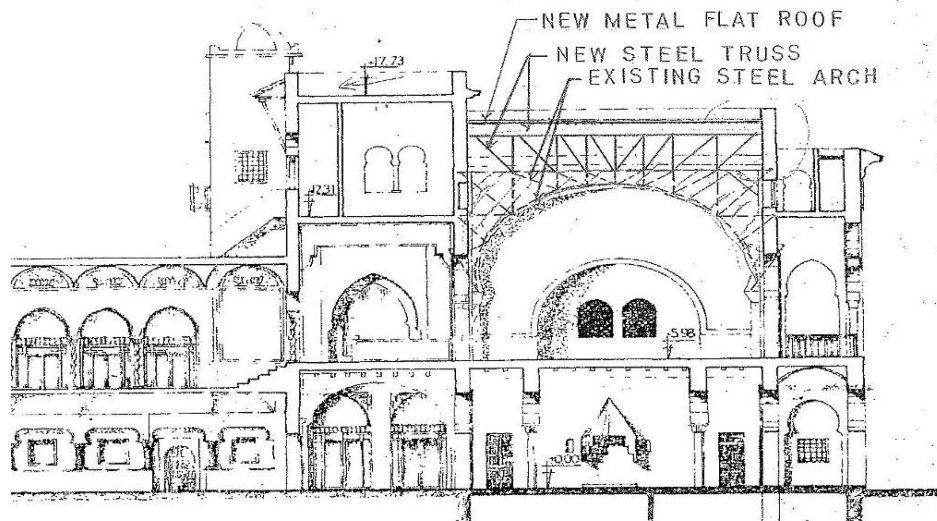


Figure 10-7 Additional Roof Truss Reinforcing for Existing Steel Arch

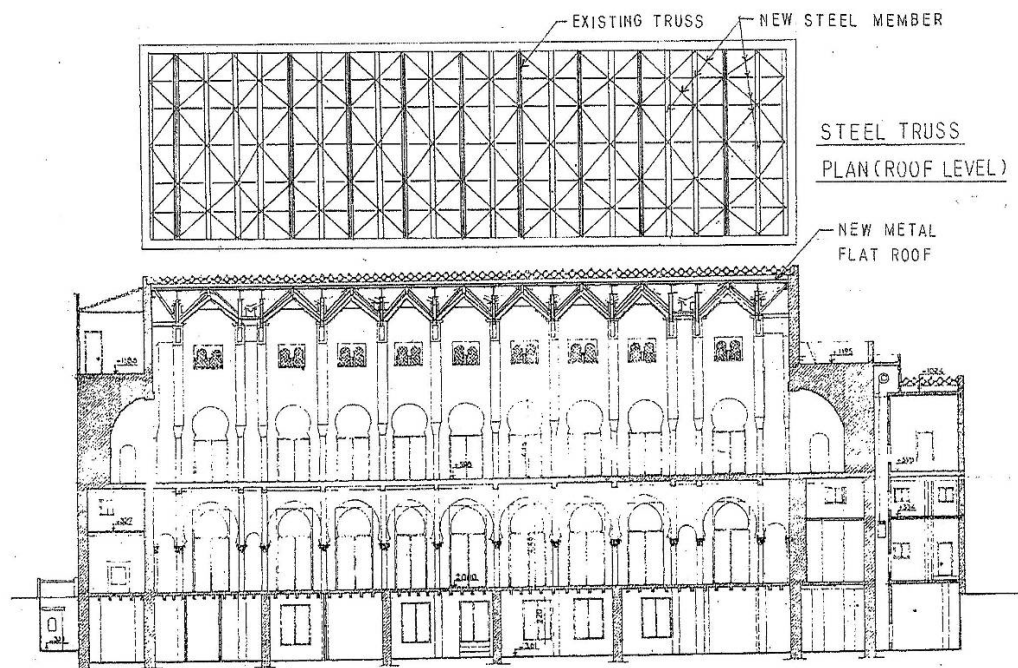


Figure 10-8 Plan and Elevation of Additional Roof Truss

(C) (Option-1) Adoption of Grouting Mortar Method for the Existing Bearing Walls

This method is employed if there are cavities in the interior of bearing walls due to old masonry wall construction methods. The old method was to provide joint material (lime or clay mortar) to the outer portions of both sides of bearing walls, and to omit the joint material in the inner portion of thicker bearing walls. Accordingly, old thick bearing walls may have interior cavities. If it is learned during repair work that there are no cavities inside of the bearing walls this method can not be applied.

Before commencement of this grouting mortar retrofit method, the volume ratio of grouting mortar in the subject bearing wall has to be checked every 3 to 5 m<sup>2</sup> of vertical surface area of the existing bearing walls.

The result of this pre-check will be judged as follows;

- A) If the volume ratio of the cavities that need to be filled with grouting mortar is less than 10% of the volume of the bearing wall, the mortar grouting method can not be applied to the subject building. Accordingly, another retrofitting plan should be applied.
- B) If the volume ratio of the cavities that need to be filled with grouting mortar is more than 10% of the volume of the bearing wall, a mortar grouting method can be applied to the subject building.

Grouting mortar is pumped in to all cavities inside of the existing bearing wall using a high pressure pump. The procedure for mortar grouting is shown in Figure 10-9 and Figure 10-10.

The grouting mortar compressive strength must be more than 25 N/mm<sup>2</sup> for all parts of the building, and 36 N/mm<sup>2</sup> or more for the 1st and 2nd floors of the Main Hall block.

During mortar grouting work, the volume ratio of grouting mortar being injected per volume of bearing wall will be checked for each bearing wall every 3 to 5 m<sup>2</sup> of vertical surface area.

If during the above grouting mortar volume checks the volume ratio of grouting mortar being injected is found to be less than 10% of the volume of the bearing wall, the grouting work will be suspended, and the constructor will inform the engineer. In this case, the grouting mortar method for the subject wall is not viable.

If the volume ratio of grouting mortar being injected is more than 35% of the volume of the bearing wall, the grouting work will be suspended, and the constructor and the engineer will check for leakage of grouting mortar, and if any are found will take measures to provide an effective leakage stop.

If the grouting mortar method is viable for le PALAIS, the cost of this retrofitting work is quite reasonable (In Japan, it is approx. 20 to 40% of replacement cost).

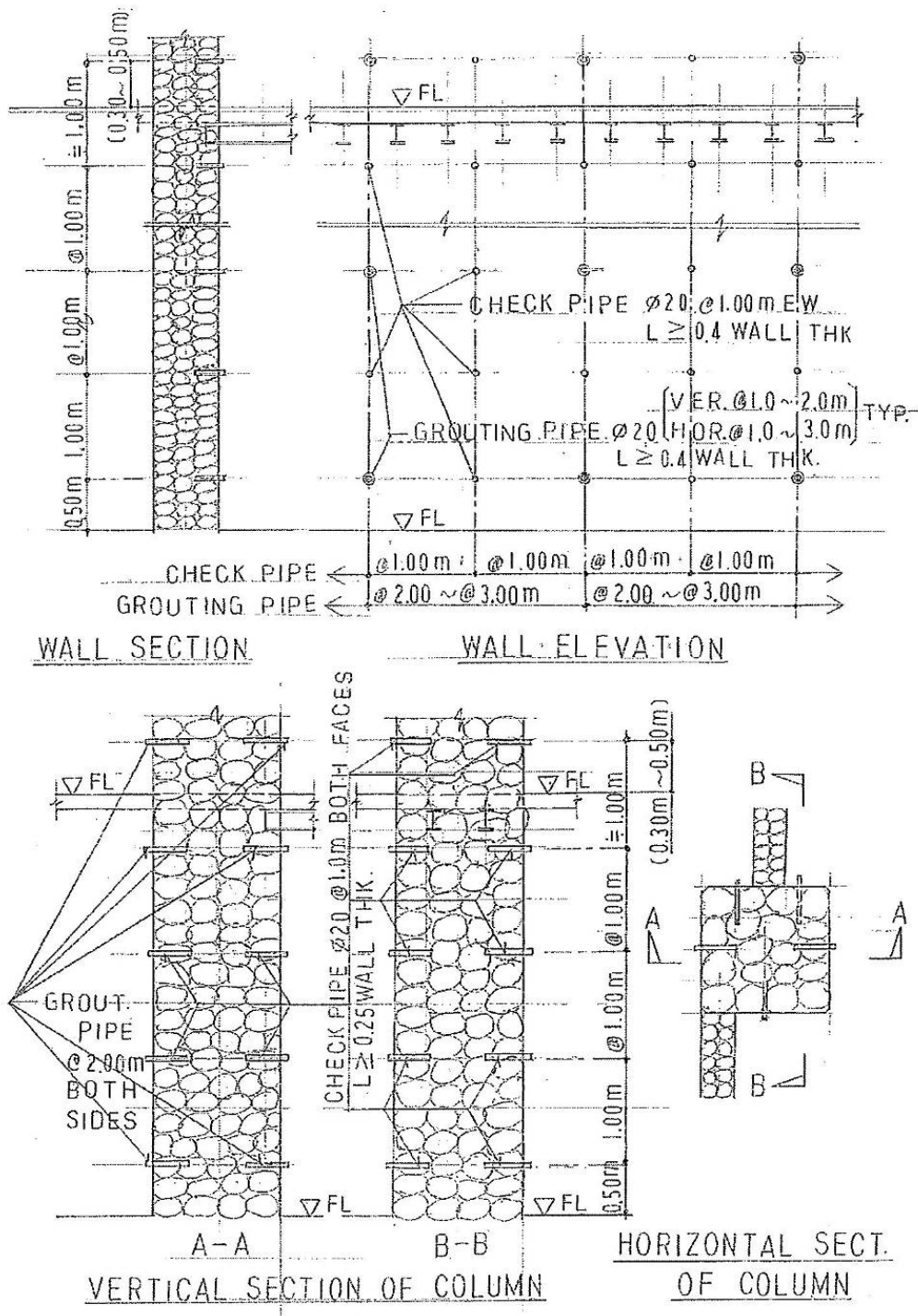


Figure 10-9 Mortar Grouting Method for Existing Bearing Walls

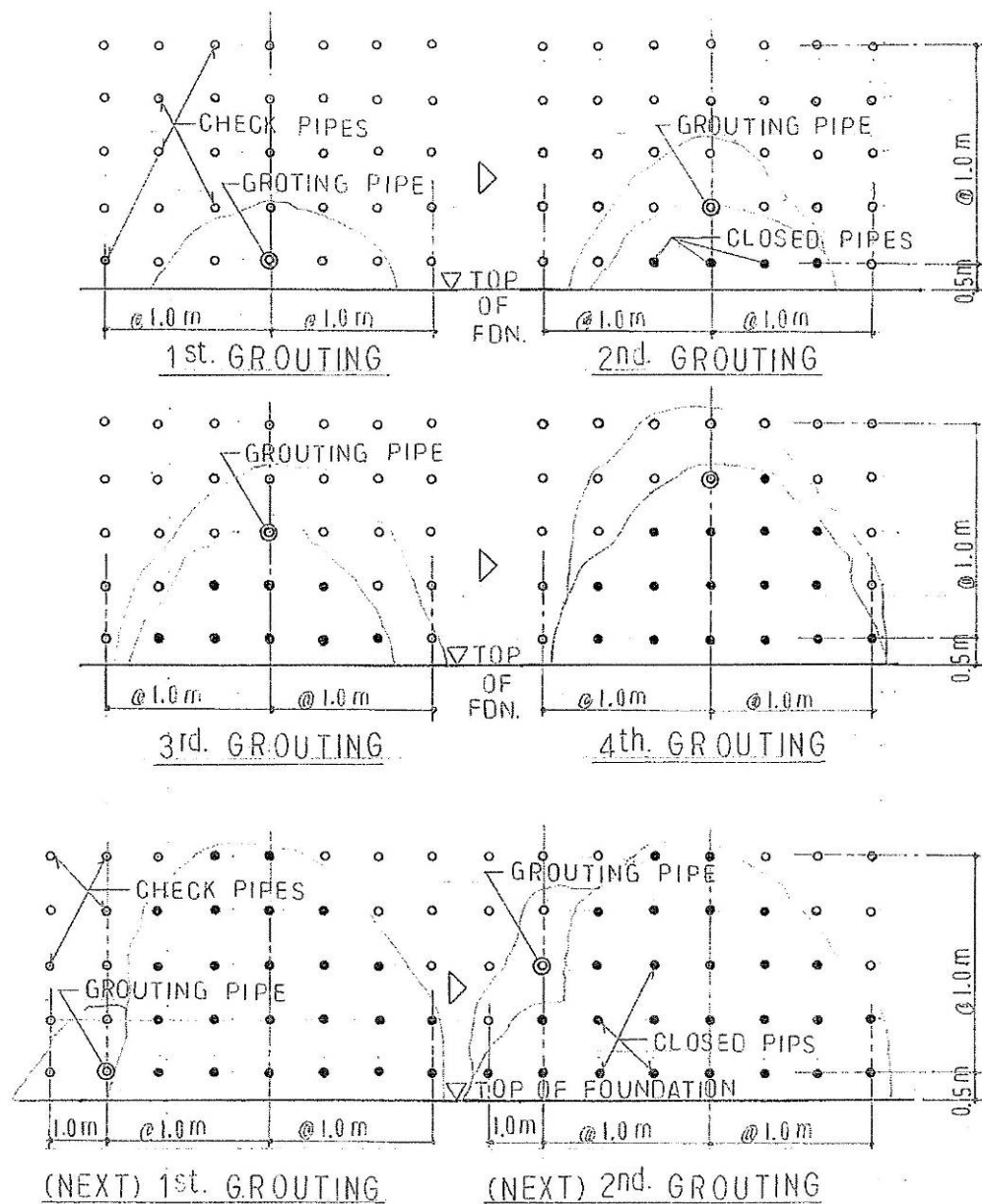


Figure 10-10 Procedure of Mortar Grouting Method

(D) (Option-2) Change the Building Use and Construct a NEW PALACE

The building use could be changed to a museum or other purpose.

The usage of the PALACE building could be changed to another purpose with necessary strengthening work to preserve human safety, for example a museum or other use.

This would then require the construction of a new Presidential PALACE Building.



The cost of this solution is very high (In Japan, it is approximately 115% to 135% of replacement cost). Moreover, this figure excludes the cost for the site for the new Palace building).

## 2) Seismic Retrofit Design for Le PALAIS

### (A) Base Isolation System

For the recommended plan for this system, refer to Chapter 10-3-2 (2) 1) (A).

Lead rubber bearing isolation devices of  $\phi$  400 and  $\phi$  550 are recommended and those are shown in Table 10-21.

Table 10-21 The Lead Rubber Bearing Isolator

Diameter of Device		Sectional area (mm <sup>2</sup> )	Recommended Max. Axial Load (kN)	Recommended Isolator
Outside (mm)	Inside (mm)			
400	150	1,080	1,080	∩
450	150	1,414	1,410	
500	150	1,787	1,780	
550	200	2,061	2,060	∩
600	200	2,513	2,510	

Note: Recommended maximum axial load on the device is assumed based on 1.0 kN/mm<sup>2</sup> of compression on the rubber.

The calculated load supported by the isolators and the number of isolators required is shown in Table 10-22.

Table 10-22 Calculated Load Supported by the Isolators and Number of Isolators Required

(Unit: kN)

Place	Weight of Super-structure	Weight of under ground Wall	Weight of 1Fl. Slab + Live Load	Weight of New RC Beam	Total Load	Isolator (Dia., Nos.)
Old Palace	26,688	4,400	3,100	2,200	36,388	$\phi$ 400: 39 Nos.
New Palace Entrance Block	19,513	3,300	2,400	1,750	26,963	$\phi$ 400: 29 Nos.
New Palace Main Hall Block	64,732	5,900	6,200	5,300	82,132	$\phi$ 550: 45 Nos., $\phi$ 400: 13 Nos.

Note: Unit weight of 1st floor slab plus live load (0.50 kN/m<sup>2</sup>) for seismic design is assumed to be 11.0 kN/m<sup>2</sup>.  
Unit weight of new RC beams which are support bearing wall is assumed to be 10.0 kN/m<sup>2</sup>.

(B) Grouting Mortar Method

For the grouting mortar method for existing bearing walls refer to Chapter 10-3-2 (2) 1) (C).

Characteristics of the grouting mortar are as follows;

Compressive strength must be more than 25 N/mm<sup>2</sup> (28 day) for all parts of the building, and more than 36 N/mm<sup>2</sup> (28 day) for the 1st and 2nd floors in the Main Hall block only

Minimum design shear strength is  $25 \times 2 / 10 \times 3 = 1.67$  N/mm<sup>2</sup> for all parts of the building, and  $36 \times 2 / 10 \times 3 = 2.40$  N/mm<sup>2</sup> for the 1st and 2nd floors in the Main Hall block only.

Total shear capacity of the existing bearing walls was calculated by the following formula;

$$V_{\text{exist.}} = \tau_0 W_a$$

where;

$$\tau_0 = 0.056 \text{ Mpa (N/mm}^2\text{)}$$

W<sub>a</sub>: Sectional area of bearing wall in each direction (m<sup>2</sup> = 10<sup>6</sup> mm<sup>2</sup>)

The required shear strength of the wall after being charged with new grouting mortar is calculated by the following formula.

$$V_{\text{req.}} = 0.304 F W - \tau_0 W_a$$

$$\text{Req. n. Ga} = 1.20 (0.304 \times 1.15 \times W - 0.056 W_a) / (1.67 \text{ or } 2.40)$$

where;

V<sub>req.</sub>: The required shear strength of the wall after being charged with new grouting mortar is calculated by the following formula.

F: Safety factor = 1.15

Req. n. Ga: Required sectional area of newly grouted mortar wall

1.20: 20% of margin in design

Required sectional areas of newly grouted mortar walls for each block were calculated as shown in Table 10-23.

Table 10-23 Required Sectional Area of New Grouting Mortar

Place			A = 0.304 F W (10 <sup>6</sup> N)	B = 0.056 W (10 <sup>6</sup> N)	A – B (10 <sup>6</sup> N)	Required new Grouting area (m <sup>2</sup> )	Req. sec. area* and percentage in Existing Bearing Wall (m <sup>2</sup> , %)
Block	Story	Direct.					
Old Palace	2 <sup>nd</sup> Fl.	X	4.43	2.40	2.03	1.46	6.6 (15%)
		Y		1.93	2.50	1.80	8.2 (24%)
	1 <sup>st</sup> Fl.	X	9.34	3.51	5.83	4.19	19.0 (30%)
		Y		3.19	6.15	4.42	20.1 (35%)
New Palace Entrance Block	2 <sup>nd</sup> Fl.	X	3.54	1.02	2.52	1.81	8.2 (45%)
		Y		1.52	2.02	1.45	6.6 (24%)
	1 <sup>st</sup> Fl.	X	6.83	1.34	5.49	3.94	17.9 (75%)
		Y		2.11	4.72	3.39	15.4 (41%)
New Palace Main Hall Block	3 <sup>rd</sup> Fl.	X	4.13	2.36	1.77	1.27	5.8 (14%)
		Y		2.39	1.74	1.25	5.7 (13%)
	2 <sup>nd</sup> Fl.	X	13.56	2.91	10.65	5.33	24.2 (47%)
		Y		2.97	10.59	5.30	24.1 (45%)
	1 <sup>st</sup> Fl.	X	22.66	3.72	18.94	9.47	43.0 (65%)
		Y		3.84	18.82	9.41	42.8 (62%)

Note: Required sectional area\* is calculated based on an assumed average void ratio of 22% in the sectional area of the existing bearing walls. This must be confirmed or revised based on the results of the on site test grouting.

### (3) Recommendations for Retrofit Methods for the Senator Office SENATE (herein after Le SENAT)

According to our seismic evaluation (Refer to Chapter 9-1), Le SENAT requires certain seismic retrofit work as soon as possible. However, since this seismic evaluation was performed based on an “assumed shear strength of the bearing wall unit of 0.056 Mpa (N/mm<sup>2</sup>)”, the actual shear strength of the joint material in the existing bearing walls should be confirmed before final design.

#### 1) Recommendations for the Seismic Retrofit Plan

Le SENAT building consists of the office space for the support personnel and the official space such as the assembly hall, the conference room, the court and the gallery. The official space is located on the centerline of the building and has a traditional and historical design on exterior and interior façades. The office space for the support personnel is located on both sides of the official space. The basic condition for the retrofit design is that it has to preserve the nature and function of the official space. The subject building has very low seismic capacity. Therefore, the bearing walls in the office space for the support personnel can be changed, but the exterior surface of walls should be kept in the present condition. Under this condition, three types of seismic retrofit plans are recommended as follows;

(A) Adoption of Reinforced Concrete (RC) Shear Walls

The new RC shear walls are to be built on the surface of the existing stone bearing walls on the inside of the office rooms. They should be connected from the top of the foundation and/or the top of the basement walls up to the shear wall through each existing floor slab. The new RC shear walls are shown in Figure 10-11 to Figure 10-16.

The compressive strength of the concrete for the new shear walls and connecting beams must be more than 25 Mpa (N/mm<sup>2</sup>) 28-day compressive strength, and the shear strength must be more than 2.0 Mpa (N/mm<sup>2</sup>).

The existing major floor system consists of steel beams and steel joists with a mortar bed (the original bed was made of tuff), and these steel members were just supported on the stone bearing walls without any fixing connections. Since these floor supports will not be stabilized on the walls during a great earthquake, new perimeter RC beams with shear connectors will have to be provided without any new RC shear walls. The new RC connecting beams are to be connected with steel studs or re-bar between the existing bearing walls and the steel beams and joists as shown in Figure 10-11.

The cost of this retrofitting work is within a quite reasonable range (in Japan, it is approx. 15% to 35% of replacement cost).

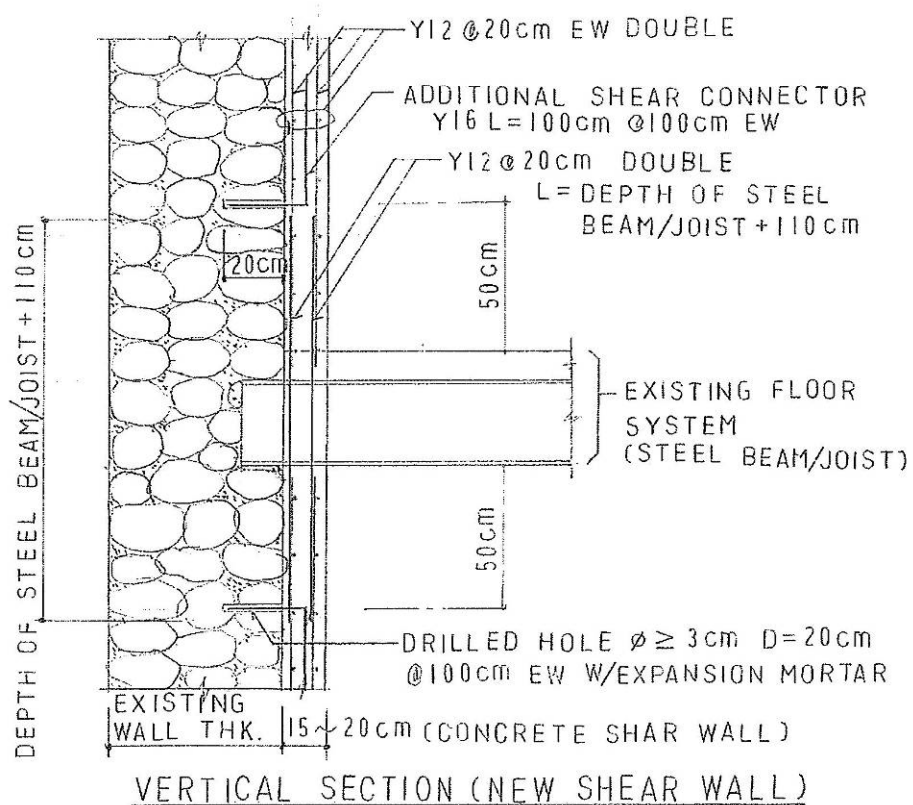
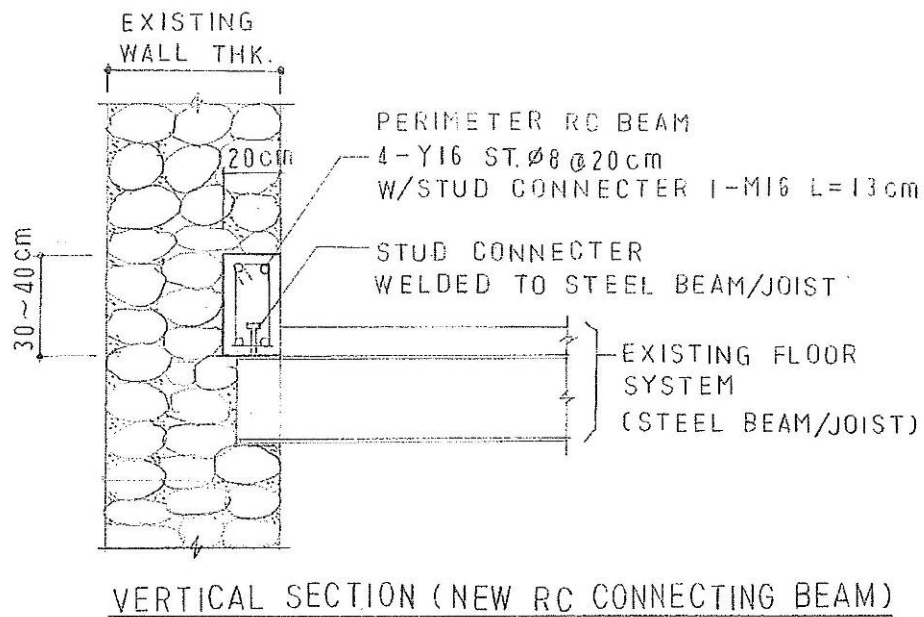


Figure 10-11 Typical details of New RC Connecting Beams and New RC Shear Walls