Group	Mission	Building	Type	Category	Document	Date of Report	Consultant
AMS-B	Bridgetown, Barbados	Chancery	Owned	1 Immediate Occupancy (IO)	Phase 2 Component 2 Seismic Evaluation	December 2013	JL Richards

This document is supplemental to the Bridgetown Chancery Phase 1/2 RSS

Purpose: To confirm seismic performance of the Chancery as per the Phase 1 recommendations and propose remedial options.

COMPONENT 2 – RETROFIT OPTIONS STUDY

Building Deficiencies

- Existing roof and second floor diaphragm
  - Inadequate diaphragm capacity and connectivity to the supporting elements;
  - Inadequate shear transfer capacity around the large central openings;
  - Inadequate capacity of the existing perimeter chord element.
- Existing columns do not have adequate capacity to withstand seismic design forces
- Existing braces do not meet strength and slenderness requirements of CSA S16-09 in compression

Seismic Retrofit Options

Option 1: Maintain the existing tension only bracing system.

- Replace the existing tension only braces with larger elements or
- Double the number of braces in each direction

Option 2: Install new tension-compression braces; replace existing braces with buckling restrained braces (BRB's).

Option 3: Install friction dampers in new braced bays adjacent to existing braced bays.

Diaphragm Reinforcing

Each of the seismic retrofit options requires the following reinforcing work, applicable to all three options:

- Improve capacity of roof and second floor diaphragms;
- Improve connectivity of the deck diaphragm to the SFRS;
- Horizontal reinforcement around the second and roof level openings;
- Replacement of existing perimeter chord element with a larger element;
- Upgrade foundation with the use of rock anchors to prevent uplift.

I. Option 1A): Replace Existing Tension Only Bracing
   a. Proposed Retrofit
      i. Replace existing tension only braces with larger tension only braces.
      ii. Work is limited to the existing bays; no new bays need to be constructed
   b. Retrofit to 150% of the Design Load
      i. 150%: Columns and connection retrofits are required at the ground and second levels

II. Option 1B): Addition of New Braced Bay Locations
   a. Proposed Retrofit
      i. The addition of new braced bays adjacent to existing braced bays distributes the seismic forces over a greater number of elements, but there will be an increase in column loads between the bays.
      ii. Existing steel frame elements would be used to support the new braced bays
   b. Retrofit to 150% of the Design Seismic Load
      i. 150%: Existing braces and connections require replacement at the ground floor level

III. Option 2: Installing New Tension-Compression Braces (BRB's)
   a. Proposed Retrofit
      i. Unlike conventional braces, BRBs have the same capacity in compression and tension, and they provide a higher level of performance and protection than the conventional tension only braces
      ii. One BRB can replace the existing cross-bracing in each bay.
   b. Retrofit to 150% of the Design Seismic Load:
      i. 150%: same as 100%.

IV. Option 3: Installing Friction Dampers in New Braced Bays
   a. Proposed Retrofit
      i. Construct new braced bays in the same location as option 1b. Nine new braced bays with friction dampers are to be installed. Or, four braced bays with friction dampers can be installed and the remaining bays can have rock anchors installed. These numbers can be further investigated if this option is selected.
      ii. Friction dampers can reduce the seismic force by 50%, so that elements outside the LFRS can be designed for lower seismic forces
      iii. Friction dampers can be installed without increasing the uplift capacity of the foundation, reducing the need for rock anchors.
      iv. No retrofit to the existing structural system would be required if additional braced bays and friction dampers are installed.

See summary table for impact of each of the proposed options.

Proposed Sequence of Work

1. Install foundation upgrades (rock anchors, baseplates, anchor bolts, etc) as required for the chosen option. All foundation work will all proceed at the same time from outside; as work is completed, the excavations will be backfilled and returned to their original condition. The work areas will be fenced off and walk ways will be rerouted.
2. Initial load path upgrades will be performed. This includes the removal of finishes and scaffolding to access the roof deck and second floor. This work will proceed one zone at a time, with safe work zones and emergency egress routes to be provided.
3. Exterior finishes in braced bay locations will be removed as required. This work will proceed two bays at a time, from the outside, with minimal impact on the interior working space.
4. Interior finishes in braced bay locations will be removed, as required, in order to complete brace installation.
5. Work areas will be returned to their original condition.
6. Mission will need to provide temporary swing space for staff affected by construction work.

Recommendations

- The most economical retrofit solution is Option 3) Friction Dampers in New Braced Bays since no foundation work is required, but diaphragm work is still required
- Initial load path upgrades and diaphragm upgrades to the LFRS should be completed regardless of which retrofit option is selected.
- Friction dampers should be designed for 150% of the design seismic load since the cost difference from 100% design seismic load is negligible.
- The number of friction dampers can be optimized if this option is selected in order to minimize/eliminate diaphragm and foundation work.

Reviewer's Notes

- The upgrades listed under "Diaphragm Reinforcing" should be performed regardless of which, if any, retrofit option is selected.
- The second most economical solution is the Option 1A) Replacing the Tension Only Bracing.

Report Reviewed by: Victoria Teng, Civil Engineering Co-op Student

Structural Engineer's Comments/Recommendations:

Notes:

- Component 1 of Phase 2 confirms the High Seismic Risk regarding the CH, even from a Life Safety perspective.
- All options have a similar duration for implementation varying between 33 and 36 weeks.
- Option 3 is the least expensive at $ 658 k and is the only option that will not require foundation work and therefore could be considered to be least intrusive.
- Options 1 and 2 are estimated to cost from $ 725 k to $ 837 k and require foundation work to install rock anchors.
- The roof and floor diaphragms are recommended by the Consultant as needing seismic reinforcing even if no further seismic work is undertaken.
- ARAF has informed ARPT that the roofing system requires replacing.
- It is believed that the best technical option would be Option 3.
- It is believed that the best overall option is Option 3.

Recommendations:

- It is recommended to implement the seismic upgrade to the roof diaphragm concurrently with the roofing membrane replacement.
- It is recommended to proceed with an Option 3 implementation (Phase 3 of the Seismic Program).

2 January 2014

X

Damian de Krom
Structural Engineer

Table 1: Comparison of the Retrofit Options for Bridgetown

		Option 1A			Option 1B			Option 2			Option 3		
		100%	150%	Notes	100%	150%	Notes	100%	150%	Notes	100%	150%	Notes
Seismic Reinforcing Required	Replace Braces at Ground Level	Yes	Yes	Replace existing tension only angle with a larger tension only element.	No	Yes	Replace existing tension only angle with a larger tension only element.	Yes	Yes	Replace Existing tension only angle, with a single tension-compression BRB.	No	No	All work includes installation of new friction dampers with no alteration of existing elements
	Replace Braces at Second Level	Yes	Yes	Replace existing tension only angle with a larger tension only element.	No	No		Yes	Yes	Replace Existing tension only angle, with a single tension-compression BRB.	No	No	
	Replace/Retrofit Columns at Ground Level	Yes	Yes	Increase Axial capacity with plates welded to the columns.	No	No		Yes	Yes	Columns are Class 3 – not allowed in a ductile BRB frame	No	No	
	Replace/Retrofit Columns at Second Level	No	Yes	Increase Axial capacity with plates welded to the columns.	No	No		Yes	Yes	Columns are Class 3 – not allowed in a ductile BRB frame	No	No	
	Replace Beams	No	No		No	No		No	No		No	No	
	Replace Brace to Column Connections at Ground Level	Yes	Yes	Remove existing gusset plate, replace with a larger plate with more weld area and adequate bolts.	No	Yes	Remove existing gusset plate, replace with a larger plate with more weld area and adequate bolts.	Yes	Yes	Existing connections will be inadequate for BRB's.	No	No	
	Replace Brace to Column Connections at Second Level	No	Yes	Remove existing gusset plate, replace with a larger plate with more weld area and adequate bolts.	No	No		Yes	Yes	Existing connections will be inadequate for BRB's.	No	No	
	Replace Connection at Base Plate	No	Yes	Increase size/number of anchor bolts at base plate.	Yes	Yes	Increase size/number of anchor bolts at baseplate.	Yes	Yes	Increase size/number of anchor bolts at base plate.	No	No	
	Tension Forces Requiring Mitigation	Yes	Yes	Install rock anchors.	Yes	Yes	Install rock anchors.	Yes	Yes	Install rock anchors. Magnitude of uplift is up to 2 times greater than other options.	No	No	
Cost Estimate C$		$ 725,340.00			$ 837,540.00			$ 804,500.00			$ 657,558.00		
Estimated Construction Schedule		36 weeks			36 weeks			33 weeks			33 weeks		
Estimated Impact on Operations		Foundation upgrades required. Braced bay replacement can proceed one at a time.			Foundation upgrades required. Braced bay replacement can proceed one at a time.			Foundation upgrades required. Braced bay replacement can proceed one at a time.			No foundation upgrades required.		

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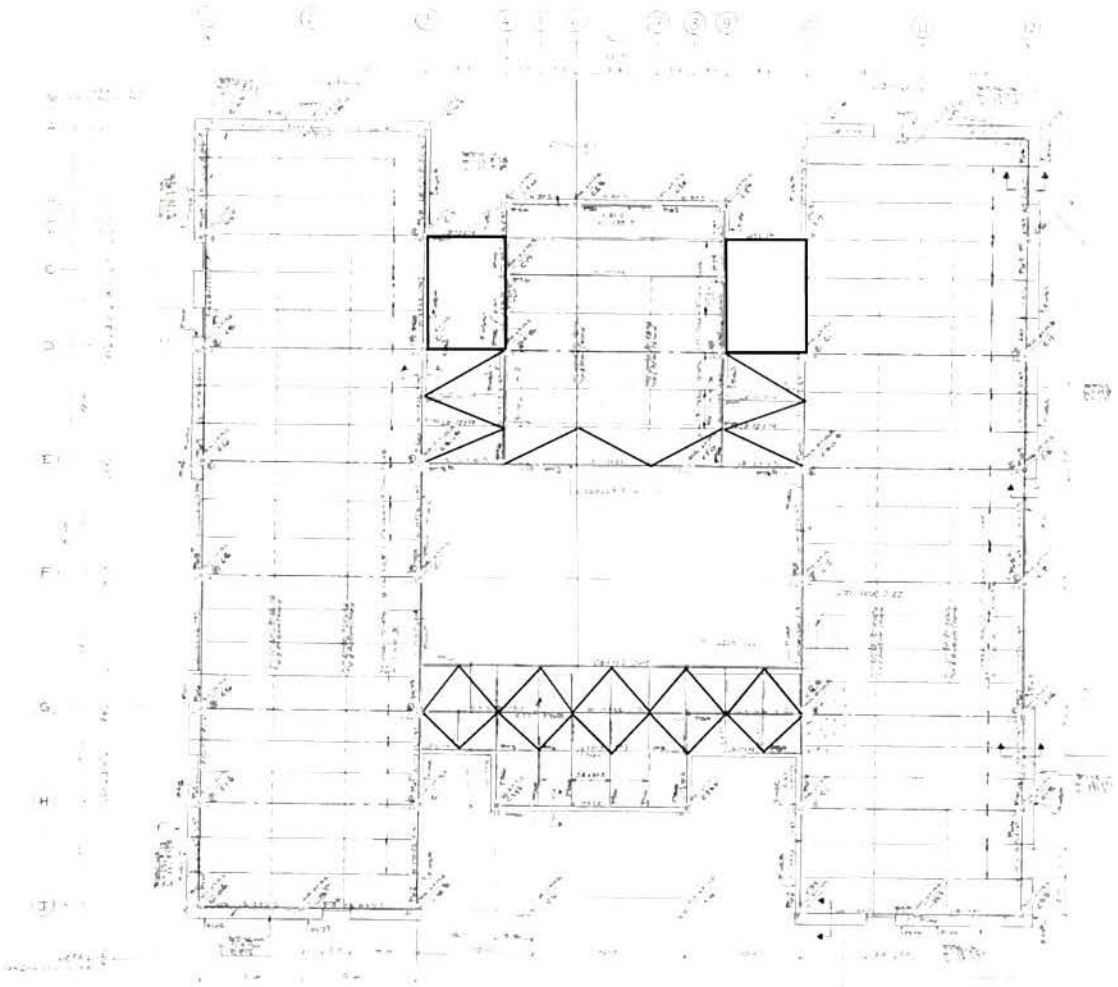

LEGEND

——— ADDED BRACING MEMBERS

——— NEW PERIMETER CHORD

J.L.Richards
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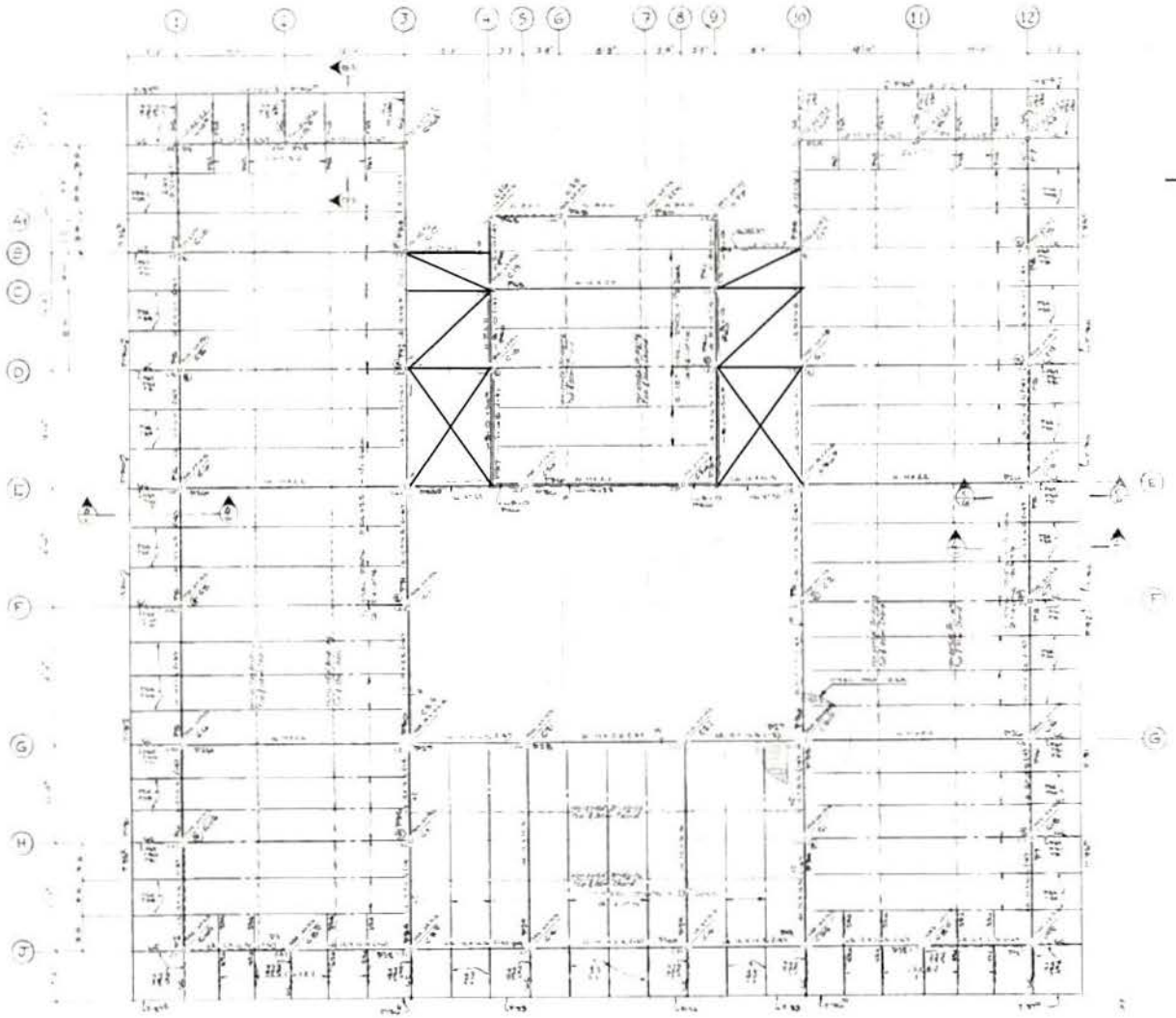
PROJECT:	BRIDGETOWN BARBADOS PHASE 2 COMPONENT 2
DRAWING:	HORIZ. REINFORCEMENT SECOND FLOOR LEVEL
DESIGN:	JAS
DRAWN:	RLB
CHECKED:	JAS
PLOTTED:	Dec09,2013
DRAWING NO.:	SK-2
JLR NO:	23423-27



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PROJECT:
BRIDGETOWN BARBADOS
PHASE 2 COMPONENT 2

DRAWING:
HORIZ. REINFORCEMENT
ROOF LEVEL

DESIGN: JAS	DRAWING NO.: SK-3
DRAWN: RLB	
CHECKED: JAS	JLR NO: 23423-27
PLOTTED: Dec04,2013	

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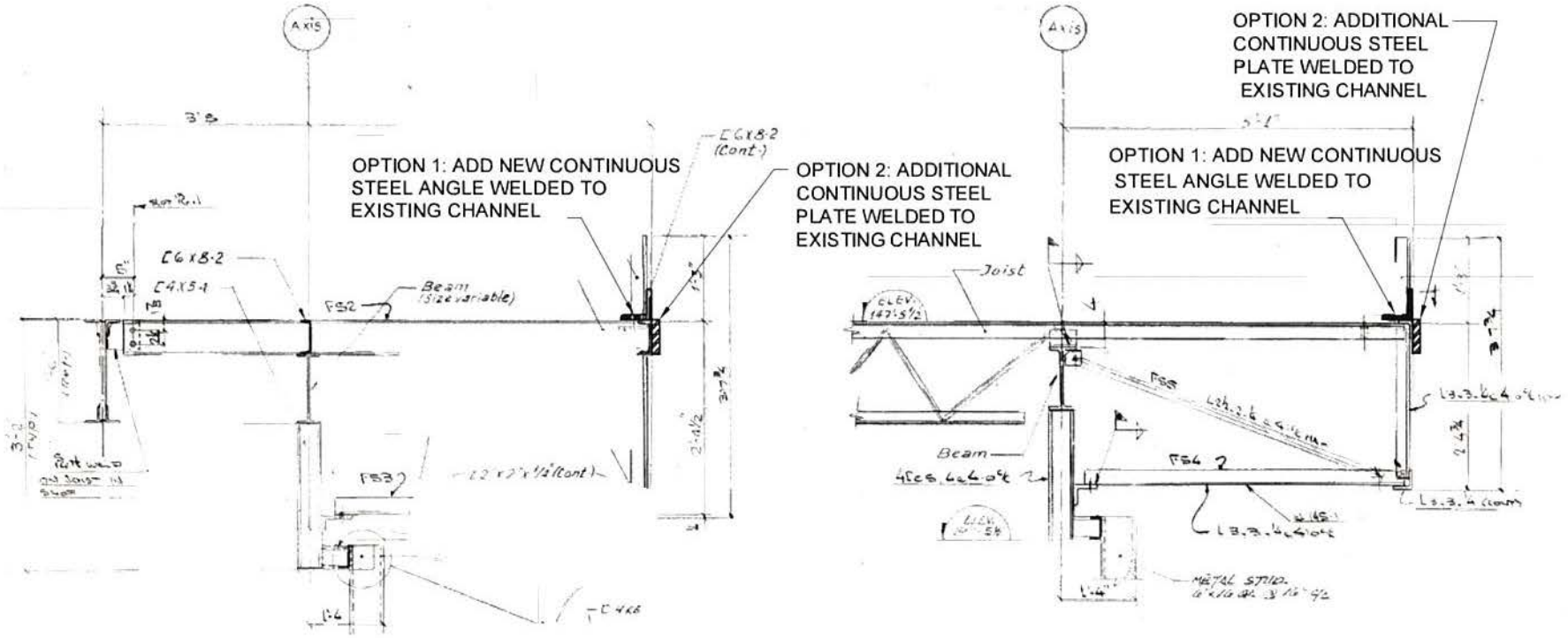

OPTION 1: ADD NEW PERIMETER ELEMENT IN CONJUNCTION WITH REPLACEMENT OF EXISTING ROOFING SYSTEM.

OPTION 2: ADD NEW PERIMETER ELEMENT. ADDITIONAL CONTINUOUS STEEL PLATE WELDED TO EXISTING CHANNEL.

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PROJECT:	BRIDGETOWN BARBADOS PHASE 2 COMPONENT 2
DRAWING:	NEW PERIMETER ELEMENT ROOF LEVEL
DESIGN:	JAS
DRAWN:	RLB
CHECKED:	JAS
PLOTTED:	Dec09,2013
DRAWING NO.:	SK-5
JLR NO:	23423-27

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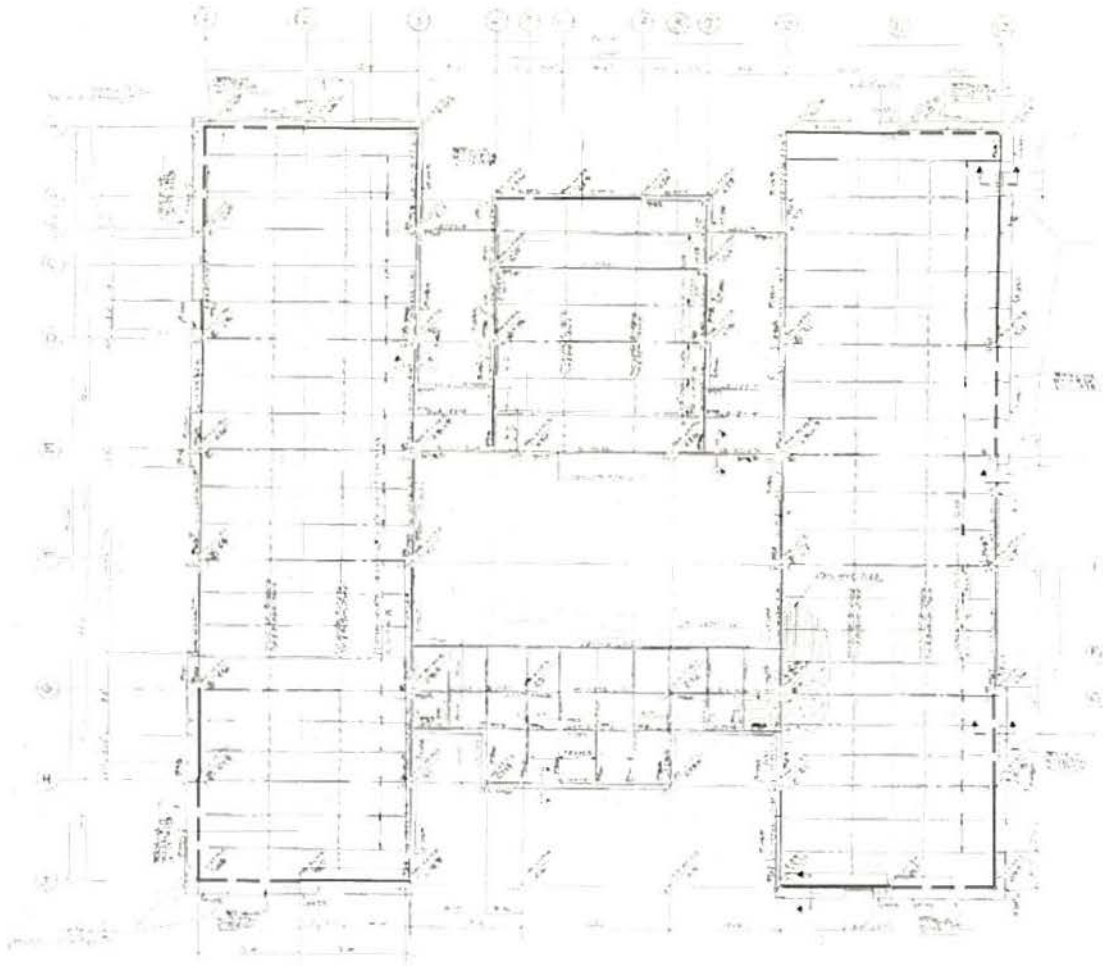

LEGEND

EXISTING BRACE BAY LOCATIONS

NEW SEISMIC BRACING LOCATIONS

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PROJECT: BRIDGETOWN BARBADOS PHASE 2 COMPONENT 2	DRAWING: PLAN LAYOUT PROPOSED ADDITIONAL BRACED BAY LOCATIONS	DESIGN: JAS DRAWN: RLB CHECKED: JAS PLOTTED: Dec09,2013	DRAWING NO.: **SK-7** JLR NO: 23423-27

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