Cupolex Building Systems
PO Box 244 84
Royal Oak
AUCKLAND

RE: CUPOLEX FLOOR SLAB

We have assessed the Cupolex Floor slab system with regard to the New Zealand Building Code sections B1, B2, E2 and H1.

B1 Structure

Perimeter footings and internal load bearing walls:

The perimeter footings and internal load bearing walls for all Cupolex designs are specifically designed as foundations using conventional methods of limiting soil bearing pressures and in some cases designing perimeter footings to span as beams between mass concrete piles. Each building is designed to resist the loads imposed based on the dead weight of the wall, floor and roof system specified.

Verification methods used for the perimeter footings and internal load bearing walls are:

B1/VM1 Loadings:	NZS4203 (AS/NZS1170 also)
B1/VM1 Concrete design:	NZS3101:Part1
B1/VM1 & B1/VM4 Foundations:	

Specific design calculations are provided with each design to justify site specific soil bearing capacities and the building self weight. For expansive soils, mass concrete piles are used around the perimeter to ensure the founding levels are sufficiently deep as to limit shrink/swell movement. In this situation the foundations are designed to span between the piles using the current loadings code (AS/NZS1170) and the concrete code NZS3101.

Refer to Appendix A for typical perimeter footing calculations

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Interior Cupolex Floor:

The cupolex floor is designed to withstand the dead and live load imposed. For residential purposes the floor topping is 40mm thick (min).

There are standard calculations issued for each floor design which justify the cupolex floor for the following loads in accordance with AS/NZS1170.

Non Garage areas: Q(udl) = 1.5kPa or Q(point) = 1.8 kN (applied over 350mm2)

Garage areas: Q(udl) = 2.5kPa or Q(point) = 13 kN (applied over 300mm x 300mm)

The cupolex floor slab is designed as a two way spanning slab which spans to the legs created at the junction of each cupolex unit (ignoring any contribution from the central leg).

The soil bearing pressure is limited to 150 kPa (dependable) at each leg where no hardfill is used under the slab. For sites with lower dependable bearing pressures, 100mm of compacted hardfill is used to ensure the leg loads are distributed sufficiently to match the dependable bearing pressures of the site down to 75kPa (dependable).

Verification methods used for the design of the Cupolex interior slab are:

B1/VM1 Loadings: NZS4203 (AS/NZS1170 also)
B1/VM1 Concrete design: NZS3101:Part1
B1/VM1 & B1/VM4 Foundations:

Further university testing was carried out to confirm that the punching shear strength calculated was correct. It was proven by testing that the punching shear strength of the cupolex slab far exceeded the required 13kN design load and failed in flexure at point loads in the region of 65kN minimum.

Functional requirements:

B1.2 The Cupolex floor system complies with this clause as it is specifically designed to resist the code loads imposed based on site specific bearing pressures of not less that 75kPa (dependable)

Performance requirements:

B1.3.1 The Cupolex floor system complies with this clause as it is specifically designed to resist the code loads imposed without rupturing or becoming unstable.

B1.3.2 The Cupolex floor system complies with this clause as the specifically designed system has a low probability of loss of amenity due to undue deformation, degradation or physical characteristics. It is designed for the site specific bearing pressures which limit deformation of supporting soils, is protected from degradation through sufficient concrete cover or protection from the

polypropylene with a design life of 50 years and it physical characteristics are verified by calculations and/or university tests.

*B1.3.3*The Cupolex floor system complies with this clause as all physical conditions likely to affect the stability of the system are accounted for in the specific design. Including

(a) Self weight	Site specific calculations
(b) Imposed gravity loads	Site specific calculations and university tests
(d) Earth pressure	Limiting bearing pressures to site specific value
(f) Earthquake	Sliding checked in design and shear keys used where required in higher seismic zones
(m) Differential movement	Bearing pressures limited and mass concrete piles used for expansive sites. Reinforced perimeter footings designed to span soft spots
(q) Creep and shrinkage	668 mesh used with sawcuts OR 665 mesh with no sawcuts
(r) Removal of support	Mass concrete piles used for expansive sites. Reinforced perimeter footings designed to span soft spots

Refer to Appendix B for Cupolex dome and topping calculations for imposed loads uniform and distributed loads.

B2 Durability

Functional requirements

B2.2 The Cupolex floor system uses materials and construction methods which ensure sufficient durability to satisfy the functional requirements of this code throughout the 50 year design life.

Performance requirements

B2.3.1

Based on B2/VM1 cl 1.3.1 Approved standards

By way of concrete cover in accordance with NZS3101: Part 1: 1995 table 5.5 the cupolex system has 50 year design life in accordance with the requirements of the building code.

Standard concrete strengths are specified as 20 Mpa for exposure classification A1 and A2. For coastal perimeter or coastal frontage zones B1 and B2 the concrete strength is increased to 25 Mpa.

Minimum cover to reinforcing mesh to the top face is 30mm
Minimum cover to the reinforcement on the sides of perimeter footings is 50mm
Minimum cover to the underside of footings is 75mm in accordance with cl 5.11.3.3

Reinforcing mesh in contact with the Cupolex dome is protected from corrosion by the Polypropylene dome which has a design life in excess of 50years.

E2 External moisture

Functional requirements

E2.2 The Cupolex floor systems provides adequate resistance to the penetration and accumulation of moisture from inside to outside and this can be demonstrated using acceptable solutions.

Peformance

E2.3.3 The areas of slab in contact with the ground is protected from absorption and transmission of moisture by a DPM in complying with E2/AS1 10.3.3. An additional barrier is provided by the Polypropylene Cupolex units.

E2.3.4 A (DPC) moisture barrier should be used between framing and the floor slab as is standard practice for all slab on grade systems.
The cupolex floor system complies with clause E2 acceptable solutions in a similar manner to conventional footings or rib raft systems.

E2.3.5 The concealed space beneath the Cupolex floor is protected from moisture ingress from below by the DPM mentioned in E2.3.3 and is effectively sealed due to the Cupolex units above preventing moisture ingress.

Additional criteria which are met by the Cupolex system include:

Concrete slab on grade:	E2/AS1 10.3.1 section (a), figure 132(b)
Damp proof membranes	E2/AS1 10.3.3
Finished floor levels	E2/AS1 10.3.5
Floor levels	E2/AS1 10.3.2 figure 132

H1 Energy Efficiency

H1.2 The Cupolex Floor system provides superior energy efficiency when compared to conventional slab on grade construction or the minimum requirements specified by the BRANZ House insulation guide with a calculated R value of 2.35 m2K/W, exceeding the required minimum R value of 1.3 m2K/W.

H1.3.2 (a) As per above the Cupolex Floor system provides adequate thermal resistance.

H1.3.2 (b) Uncontrollable air flow is controlled as the area beneath the slab is sealed.

H1/VM1 clause 1.4.1 Thermal resistance (R-values) have been calculated in accordance with NZS4214.

Refer to Appendix C for thermal resistance calculations in accordance with NZS4214.

SUMMARY OF SPECIFIC CUPOLEX FLOOR SLAB REQUIREMENTS TO COMPLY WITH THE NEW ZEALAND BUILDING CODE

B1 Structure

Ground conditions	100kPa allowable bearing (150kPa dependable) with 15 sand blinding over cut inorganic ground. 50kPa allowable bearing (75kPa dependable) with 15 sand blinding and 100mm of compacted hardfill over cut inorganic ground. Expansive sites with a characteristic ground movement ys>30mm to have specifically designed perimeter piling of either 450mm or 600mm depth. Perimeter footings to be specifically design based on the building proposed and the associated dead and live loads.

B2 Durability

Concrete:	Structural mix Grade 20 Mpa, zones A1 and A2 Structural mix Grade 25 Mpa zones B1 and B2 13mm or 10mm aggregate 40mm minimum topping thickness at apex of domes
Cover	30mm top cover to internal mesh and reinforcement 50mm side cover to perimeter footings and internal footings 75mm bottom cover to perimeter footings and internal footings
Reinforcement	668 mesh to be used with sawcuts on a nominal 6mx6m grid as per specific documentation OR; 665 mesh with no saw cuts OR, Equivalent loose bars to achieve cross sectional area of the above mesh Grade E500 reinforcement to be used

E2 External Moisture

DPM	A DPM complying with E2/AS1 10.3.3 and/or 0.25mm (min) virgin polyethylene in accordance with E2/AS1 10.3.4 DPM to extend under the full area of the slab including the perimeter footing in accordance with E2/AS1 figure 132. DPM to be laid on a minimum of 15mm of sand blinding over cut inorganic ground (or compacted hardfill over cut inorganic ground)

Floor levels	To comply with E2/AS1 10.3.5
Service Penetrations	Service penetrations for sanitary sewers, stormwater, water supply etc are to be sealed by taping Services up to 125mm diameter can penetrate the Cupolex domes at any location including through the central leg except at the four 'feet' of the Cupolex where they bear onto the ground

We trust that the above adequately explains the Cupolex System with respect to the New Zealand Building code. It should be noted that all floors are specifically designed by a Chartered Professional Engineer for site specific ground conditions and building specific loads and we are not seeking to have this product approved as a generic system at this stage.

While other councils and countries acceptances do not have any influence on your assessment by way of further evidence as to the systems durability and 'in service history' in accordance with B2/VM1 clause 1.1 we have the following points to make.

- Other councils have accepted this system throughout New Zealand including but not limited to Auckland City, Manukau, Waitakere, North Shore, Rodney, Tauranga, Dunedin, Christchurch.
- Over 6 million square metres of cupolex has been constructed throughout Europe
- Cupolex is being used throughout Europe, Russia, Canada, North America and Mexico as well as Australasia
- Cupolex is an approved for use in accordance with the Eurocode.
- We are not aware of any issue involving strength or durability within New Zealand or the rest of the world.

Please advise if you require further information at this stage.

Yours faithfully
Per: HFC: Foundations Ltd

Rob Foster
DIRECTOR

APPENDIX A

- Typical perimeter footing calculations
- Perimeter footing calculations for spanning between piles

APPENDIX B

- Cupolex floor slab capacity calculations including punching shear checks for garage and non garage areas

APPENDIX C

- Thermal resistance based on NZS4214:1977

HFC FOUNDATIONS LTD Civil and Structural Consulting Engineers	CUPOLEX DOME SLAB DESIGN FOR: CUPOLEX BUILDING SYSTEMS [redacted]	Proj. No. Date Page:	C10032 Apr-08 A4

EXTERNAL FOOTINGS

HOUSE DATA		DEAD (G)	LIVE (Q)	
LIGHT ROOF:	7.9 m maximum roof span x 0.25 kPa	1.14	1.14	[kN/m]
WALL:	2.4 m high brick wall x 1.8 kPa	4.32		[kN/m]
	300 wide footing	2.16		[kN/m]
	Ground floor G = 2.16 x 0.6	1.30		[kN/m]
	Ground floor Q = 1.5 x 0.6		0.90	[kN/m]
	TOTAL	**8.91**	**2.04**	**[kN/m]**

Wult = 1.2G + 1.6Q = **13.96** kN/m

Exterior footing width: **300** mm

Ultimate Bearing load on external footing : **47** kPa < **150 kPa** **OK**

SLIDING

SEISMIC ZONE FACTOR Z < 0.2, INTERMEDIATE SOILS => C < 0.4

COEFFICIENT OF FRICTION = 0.4 THEREFORE SLIDING OK BY INSPECTION

SETTLEMENT: SOIL PRESSURES

USE LONG TERM LIVE LOAD REDUCTION FACTOR = 0 FOR ROOFS

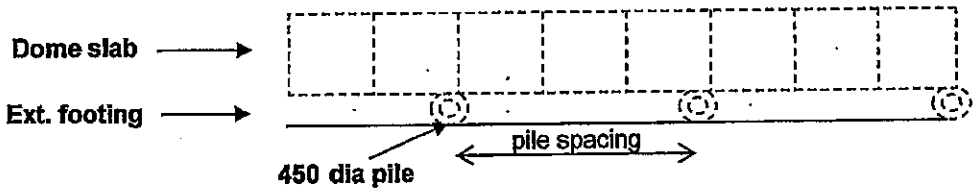
Exterior footing width = 300 mm

Max bearing load for settlement = 30.91 kPa

HFC: HARRIS FOSTER Civil and Structural Consulting Engineers	CUPOLEX DOME SLAB DESIGN FOR: [redacted]	Proj. No: C8343 Date: Sep-06 Page: B1

MASS CONCRETE PILE DESIGN:

Exp. Soil clasification: MODERATELY EXPANSIVE



Exterior wall line load:			11.81	kN/m
Cupolex Dome Slab trib width:	0.6 m	=>1.2Wg =	1.56	kN/m
Live load Q:	1.5 kPa	=>1.6Wq =	1.44	kN/m
		TOTAL	**14.80**	**kN/m**

Typical exterior footing with 2 XD12's bottom & 668 mesh + 1XD12 top

Limit ϕM to 16.7kNm	=> Lmax =	3.66	m
Limit ϕV to 14.7kN	=> Lmax =	3.21	m

Use 450dia mass concrete piles @ 2.4 m c/c spacing

Load per pile:	**35.52**	kN	**OK**
Ultimate end bearing = 225 kPa	=> Max load per pile = **35.78**	kN	

Use 450 dia mass concrete piles embeded 600mm below underside of slab

APPENDIX B

- Cupolex floor slab capacity calculations including punching shear checks for garage and non garage areas

HFC FOUNDATIONS LTD Civil and Structural Consulting Engineers	CUPOLEX DOME SLAB DESIGN FOR: CUPOLEX BUILDING SYSTEMS [redacted]	Proj. No. Date Page:	C10032 Apr-08 A2

SLAB DESIGN

1. GENERAL LIVING AREAS

DEAD (G)	Slab =	24 x 0.09 = (average)	2.16	kN/m²	
	SDL =		0.50	kN/m²	
	Total =		**2.66**	kN/m²	
LIVE (Q)	Domestic:		**1.50**	kN/m²	
		=> 1.2G + 1.6Q =	**5.59**	kN/m²	
Two way spanning slab:		$L_x = L_y$ =	0.50	m	
	Mult =	5.59 x 0.5² / 16 =	**0.09**	kNm/m	
668 Mesh:	A_s =		83.8	mm²	
	F_y =		500	Mpa	
	d =		30	mm	
	a =	(83.8 x 500) / (0.85 x 1000 x 25) =	1.97	mm	
	M =	0.85 x 83.8 x 500 x (30 - 1.97 / 2)	1.03	kNm	**OK**

Min. shrinkage reinforcement: 0.7 / 500 x 90 x 1000 = 126 mm²
668 Mesh with sawcuts on a 6m x 6m grid or an equivalent area
665 Mesh with no sawcuts 147 mm² **OK**

NOTE: Provide adequate saw cuts, control joints and trimming bars at all internal corners

Punching shear perimeter bo = (sqrt (350mm²) + 2 x 15) x 4 = 195 mm
Vn = 1.8e3 / (0.75 x 30 x 195) = 0.41 Mpa < 0.2 sqrt (20) = 0.89 Mpa **OK**

2. GARAGE AREAS

DEAD (G)	Total =		**2.66**	kN/m²	
LIVE (Q)	Garage:		**2.5**	kN/m²	
	P (applied to external panels) =		**4.5**	kN	
	P (applied to internal panels) =		**9**	kN	
		=> 1.2G + 1.6Q =	**7.19**	kN/m²	
Two way spanning slab:		$L_x = L_y$ =	0.50	m	

Mult = 7.19 x 0.5² / 16 =	**0.11**	or	<	1.03 kNm	**OK**
Mult = 1.2 x 2.66 x 0.5² / 16 + 1.6 x 4.5 x 0.5 / 8 =	**0.50**	external	<	1.03 kNm	**OK**
Mult = 1.2 x 2.66 x 0.5² / 16 + 1.6 x 9 x 0.5 / 16 =	**0.50**	internal	<	1.03 kNm	**OK**

Punching shear perimeter bo = (300mm + 2 x 15) x 4 = 1320 mm
Vn = 9e3 / (0.75 x 30 x 1320) = 0.3 Mpa < 0.2 sqrt (20) = 0.89 Mpa **OK**

HFC FOUNDATIONS LTD Civil and Structural Consulting Engineers	CUPOLEX DOME SLAB DESIGN FOR: CUPOLEX BUILDING SYSTEMS [redacted]	Proj. No. Date Page:	C10032 Apr-08 A3

BEARING UNDER SLAB

Allowable bearing pressure:	100	kPa
Ultimate bearing pressure:	150	kPa

Load is transferred via the cupolex structural dome to dome legs

Direct bearing area of each dome leg:	0.0134	m²
Bearing from central leg of each dome:	0.0005	m²
Additional bearing area from PONTEX:	0	m²
Total contact area:	0.0139	m²

Check ultimate bearing under a typical 560 x 560 panel

Ultimate Bearing load from Dome: (living areas)	4.99 x 0.56² / 0.0139 =	112.63	kN/m²	
		112.63	**kN/m²**	**OK**
Ultimate Bearing load from Dome: (garage areas)	6.59 x 0.56² / 0.0139 =	148.72	kN/m²	
		148.72	**kN/m²**	**OK**

SETTLEMENT SOIL PRESSURES

USE LONG TERM LIVE LOAD REDUCTION FACTOR =		0.4	
Living areas :	Load = (2.16 + 0.4 x 1.5) x 0.56² / 0.0139 =	62.27	kPa
Garage areas:	Load = (2.16 + 0.4 x 2.5) x 0.56² / 0.0139 =	71.29	kPa
	=> Max bearing load for settlement =	**71.29**	

APPENDIX C

- Thermal resistance based on NZS4214:1977