3.3 SPECIFIC DESIGN – HIBOND FLOORING

3.3.1 INTRODUCTION

The Hibond Flooring System has been designed to comply with BS 5950 using the relevant load combinations therein and the relevant clauses of the New Zealand Building Code. Detailed analysis and comprehensive physical testing have enabled load/span tables to be established using the limit states design philosophy.

Data presented in this manual is intended for use by structural engineers. Use of the Hibond Flooring System in applications other than uniformly distributed loads or outside the scope of this manual will require specific design.

A design yield strength of 550 MPa for 0.75mm base metal thickness (BMT) Hibond and 520 MPa for 0.95mm BMT Hibond has been used.

A minimum 28 day compressive strength of 25 MPa for high grade concrete has been assumed.
A minimum Hibond flooring slab thickness of 110mm has been used in this manual, in accordance with BS 5950.

The self weight of the Hibond Flooring System (including the concrete) has been included in the load tables.

3.3.2 DESIGN CONSIDERATIONS

Formwork

Where Hibond sheet is used as formwork, the trapezoidal shape of the profile provides resistance to wet concrete (G) and construction loads (Q). Maximum formwork spans given in Section 3.3.4.1 Hibond Formwork Tables are based on design checks for bending, web crushing, vertical shear, combined actions and deflection.

Hibond sheets must be laid in one continuous length between permanent supports. Short sheets of Hibond must never be spliced together to achieve the span between temporary or permanent supports.

Composite Slab

Design capacity of the Hibond Flooring System is largely dependent on interaction between the concrete and the Hibond sheet commonly referred to as shear bond. Shear bond is a combination of chemical bond between the concrete and the Hibond sheet and mechanical bond between the concrete and the embossments in the webs of the Hibond sheet. This allows tension forces to be transferred from the concrete into the Hibond sheet.

Capacities for the Ultimate Limit State were derived for positive bending, shear bond, vertical shear and negative bending as appropriate. Each of these values was back substituted into the design combinations for the applied actions using 1.4 (dead load) + 1.6 (superimposed load).

The minimum resulting superimposed load, from all actions (including deflections), was used in the tables.

Appropriate imposed floor actions (Q) should be determined in accordance with AS/NZS 1170.1. All superimposed dead load (G_{SDL}) is then added to the imposed action (Q) to give a design superimposed load (G_{SDL} + Q) expressed in kPa for direct comparison with the tabulated data in Section 3.3.5 Hibond Composite Slab Load Span Tables.

Fire Design

Fire resistance for the Hibond Flooring System may be achieved by several methods. These include placement of additional reinforcement, spray-on insulation retardant, placement of suspended ceilings, and increasing the overall slab thickness. We have considered placement of additional reinforcement in the fire design tables.

This method is based on resistance to collapse (stability), the ability of the Hibond floor slab to prevent flames passing through cracks formed in the slab (integrity) and limiting the temperature increase on the unexposed side of the Hibond floor slab (insulation).

The fire design tables are based on design checks for bending (shear is rarely critical), in accordance with NZS 3101, based on the load combination $G + \psi_{\ell}Q$ for single spans which are effective in fire emergency conditions (where ψ_{ℓ} is the factor for determining quasi-permanent values for long term actions). Full design methodology is provided in HERA Report R4-82.

The fire design tables include a superimposed dead load (G_{SDL}) of 0.5 kPa in order that an imposed action (Q) can be compared directly with the tables in Section 3.3.6 Fire Design Tables.

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3.3.2 DESIGN CONSIDERATIONS *continued*

Additional Reinforcement

Mesh Reinforcement

Mesh reinforcement is placed at minimum cover (according to durability requirements outlined in NZS 3101 Section 3.11) in order to provide:

- Control of cracks caused by shrinkage during curing.
- Nominal continuity reinforcement over supporting members where a floor is designed as a series of simply supported Hibond floor slabs.

For propped construction consideration should be given to increasing nominal continuity reinforcement over supports as crack widths will increase when props are removed. Guidance on crack width tolerances is given in NZS 3101 and HERA Report R4-113.

Consideration should be given to orientating the top bar of the mesh to be parallel to the span of the steel sheet. This will provide the optimum nominal continuity from the mesh.

The following guide features mesh sizes for various slab thicknesses based on the degrees of crack control recommended in AS 3600 in conjunction with the exposure classification, concrete strengths and cover to reinforcing in NZS 3101.

These guidelines do not cover special requirements for reinforcement at locations where the slab is subject to high stresses due to deformation compatability (for example around columns).

Where NZS 3101 requires explicit crack control, this must be specifically determined by the design engineer.

1. For composite slabs fully enclosed within a building except during construction (generally exposure classification A1)

AS 3600 Criteria Design Slab Thickness DS (mm)	Minor		Moderate		Strong	
	Non-Ductile	Super Ductile	Non-Ductile	Super Ductile	Non-Ductile	Super Ductile
110	665	SE62	663	SE82	2 x 663	2 x SE82
120	665	SE62	2 x 665	2 x SE62	2 x 663	2 x SE82
130	665	SE62	2 x 665	2 x SE62	HD12 @ 250	HD12 @ 250
140	663	SE82	2 x 663	2 x SE82	HD12 @ 200	HD12 @ 200
150	663	SE82	2 x 663	2 x SE82	HD12 @ 175	HD12 @ 175
160	663	SE82	2 x 663	2 x SE82	HD12 @ 175	HD12 @ 175
170	663	SE82	2 x 663	2 x SE82	HD12 @ 150	HD12 @ 150
180	2 x 665	2 x SE62	HD12 @ 250	HD12 @ 250	HD12 @ 150	HD12 @ 150
190	2 x 665	2 x SE62	HD12 @ 200	HD12 @ 200	HD12 @ 100	HD12 @ 100
200	2 x 665	2 x SE62	HD12 @ 200	HD12 @ 200	HD12 @ 100	HD12 @ 100

Note:

a. For nominal continuity reinforcement over supporting members where a floor is designed as a series of simply supported Hibond floor slabs, use the 'minor' column in the table above.

b. Where ductile steel reinforcing bars (eg H16@200) are used the maximum area of longitudinal top steel required is the **greater** of 75% of the area of transverse steel required in the table above or the amount of longitudinal steel required for continuity from the load span tables in Section 3.3.5 or that determined by specific design. Reinforcing bars are Grade 500 to AS/NZS 4671.

c. Super Ductile wire mesh is based on a minimum 500MPa tensile wire.

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3.3.2 DESIGN CONSIDERATIONS *continued*

2. For composite slabs in exposure classification A2 moderate or strong crack control is always required.

Required Slab Thickness (mm)	AS 3600 Criteria Design Slab Thickness DS (mm)	Moderate		Strong	
		Non-Ductile	Super Ductile	Non-Ductile	Super Ductile
120	110	2 x 665	2 x SE62	2 x 663	2 x SE82
130	120	2 x 665	2 x SE62	HD12 @ 250	HD12 @ 250
140	130	2 x 665	2 x SE62	HD12 @ 200	HD12 @ 200
150	140	2 x 663	2 x SE82	HD12 @ 175	HD12 @ 175
160	150	2 x 663	2 x SE82	HD12 @ 175	HD12 @ 175
170	160	2 x 663	2 x SE82	HD12 @ 150	HD12 @ 150
180	170	2 x 663	2 x SE82	HD12 @ 150	HD12 @ 150
190	180	HD12 @ 250	HD12 @ 250	HD12 @ 125	HD12 @ 125
200	190	HD12 @ 200	HD12 @ 200	HD12 @ 125	HD12 @ 125
210	200	HD12 @ 200	HD12 @ 200	HD12 @ 100	HD12 @ 100

Note:

a. To illustrate the effect of exposure classification on crack control requirements the slab thickness has been increased by 10mm to meet the minimum cover requirements of NZS 3101. This assumption means that longitudinal top steel requirements over supporting members can be designed using the load span tables in Section 3.3.5, provided that the extra thickness is treated purely as superimposed dead load and the composite slab is designed to the original design slab thickness.

b. Where ductile steel reinforcing bars (eg H16@200) are used the maximum area of longitudinal top steel required is the **greater** of 75% of the area of transverse steel required in the table above or the amount of longitudinal steel required for continuity from the load span tables in Section 3.3.5 or that determined by specific design. Reinforcing bars are Grade 500 to AS/NZS 4671.

3. For composite slabs in exposure classification B1 strong crack control is always required.

Required Slab Thickness (mm)	AS 3600 Criteria Design Slab Thickness DS (mm)	Strong	Strong Ductile
120	110	HD12 @ 250	HD12 @ 250
130	120	HD12 @ 200	HD12 @ 200
140	130	HD12 @ 200	HD12 @ 200
150	140	HD12 @ 175	HD12 @ 175
160	150	HD12 @ 150	HD12 @ 150
170	160	HD12 @ 150	HD12 @ 150
180	170	HD12 @ 125	HD12 @ 125
190	180	HD12 @ 125	HD12 @ 125
200	190	HD12 @ 125	HD12 @ 125
210	200	HD12 @ 100	HD12 @ 100

Note:

a. To illustrate the effect of exposure classification on crack control requirements the slab thickness has been increased by 15mm to meet the minimum cover requirements of NZS 3101. This assumption means that longitudinal top steel requirements over supporting members can be designed using the load span tables in Section 3.3.5, provided that the extra thickness is treated purely as superimposed dead load and the composite slab is designed to the original design slab thickness.

b. Ductile requirements have been provided for this exposure classification to provide the flexibility that longitudinal bars could be used in conjunction with the above for negative steel requirements.

c. Where ductile steel reinforcing bars (eg H16@200) are used the maximum area of longitudinal top steel required is the **greater** of 75% of the area of transverse steel required in the table above or the amount of longitudinal steel required for continuity from the load span tables in Section 3.3.5 or that determined by specific design. Reinforcing bars are Grade 500 to AS/NZS 4671.

d. Composite slabs in exposure classification B2 and C will require a thicker slab than those for B1 above and a higher strength concrete – therefore specific design to NZS 3101 is required.

3.3.2 DESIGN CONSIDERATIONS *continued*

Ductile Reinforcement

Ductile reinforcement (to elongation requirements of BS 4449) may also be required in the following instances:

- To gain full continuity over supporting members in continuous spans (refer Section 3.3.5 Hibond Composite Slab Load Span Tables).
- To increase the fire resistance of the floor slab (refer Section 3.3.6 Fire Design Tables).
- To distribute loads around openings in the floor slab.
- To provide negative reinforcement necessary for floor slabs used as cantilevers (where the contribution of the Hibond sheet is neglected in design).
- Where a point load is not fixed in position and can occur anywhere on the floor slab (for example car parks), placement of transverse reinforcement is required throughout the slab (minimum area as for line loads).
- When used as transverse reinforcement to distribute point loads and line loads; and resist transverse bending in the composite slab as a result of point loads (refer Section 3.3.10 Design Examples). The following two cases need to be considered.

$P_Q \leq 7.5$ kN

For a discrete point load ≤ 7.5 kN it is practical to use 2 – H10 transverse bars over the effective width of the Hibond slab (b_{eb} – refer BS 5950: Part 4 Clause 6.7) centred about the point load.

Where line loads perpendicular to the direction of slab span are present (≤ 7.5 kN/m), transverse reinforcing bars with a minimum cross sectional area of $2(D_s - 55)$ mm^2 per metre of load length (over the effective width of the line load) is required.

This equates to: H10 @ 400mm centres for composite slabs 110-150mm
H12 @ 400mm centres for composite slabs 160-200mm

Line loads running parallel to the span should be treated as a series of discrete point loads.

$P_Q > 7.5$ kN

For a discrete point load > 7.5 kN, transverse reinforcement is required to satisfy the following moment resistance.

$M^*_{trans} = P^* b_{eb} / (15w)$ where $w = L/2 + b_1$ and $w \ngtr L$

Where M^*_{trans} = Factored bending moment in the transverse direction
P^* = Factored concentrated point load
b_{eb} = Effective width of slab
L = Span of composite slab
b_1 = Concentrated load length in direction of slab span

Where line loads perpendicular to the direction of slab span are present (> 7.5 kN/m), P^* is represented as a factored load per metre and b_{eb} is taken as equal to one metre.

Line loads running parallel to the span should be treated as a series of discrete point loads.

This requirement is based on recommendations from the Composite Deck Design Handbook by Heagler RB, Luttrell LD and Easterling WS; published by The Steel Decking Institute, Illinois 1997.

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3.3.2 DESIGN CONSIDERATIONS *continued*

Noise Control
Design guidance on Sound Transmission Class (STC) and Impact Insulation Class (IIC) values for Hibond Flooring Systems has been obtained through physical testing. This is covered in detail in Section 3.3.7 Noise Control.

Floor Vibration
As a guide to designers, the limits expressed in the composite slab design tables represent the maximum span of the Hibond floor slab recommended for in-service floor vibration of an open plan commercial office floor with a low damping ratio (few small partitions) and a residence with higher damping (many full height partitions). Specific design is required to check other types of floor use. This represents the slab response of a person traversing the floor, but does not account for the dynamic response of the supporting structure.

For further information, including a design example, refer Section 3.3.8 Floor Vibration.

Thermal Insulation
Design guidance on thermal resistance (R) values for Hibond floor slabs to NZS 4218 is covered in Section 3.3.9 Thermal Insulation.

In Floor Heating
Where in floor heating is to be used in a Hibond composite slab, consideration should be given to the structural impact of placing heating systems within the compression zone of the floor slab. For example the overall slab thickness could be increased to compensate for any loss of structural integrity caused by the inclusion of in floor heating.

Two systems are commonly available:

- Water, utilising polybutylene tubes up to 20mm outside diameter and spaced as closely as 200mm with minimum 25mm top cover.
- Electrical, utilising wires up to 8mm outside diameter and spaced as closely as 100mm.

Both systems are typically attached directly to the top of the shrinkage mesh, in a pattern determined by the wall layout above the floor in question.

The in floor heating system must not be used to cure the slab as it will cause excessive cracking.

Hibond Design Wizard
Dimond offers the Hibond Design Wizard available as a complimentary CD for engineers and specifiers. (Call 0800 775 777 to order your copy.)

The Hibond Design Wizard is a comprehensive design tool composed of a preliminary design module and a detailed design module. It covers a range of composite designs with Hibond floor slabs and composite secondary/primary beams, providing rapid design solutions and evaluation of alternatives.

The Wizard includes flooring scenarios for unpropped, propped and pre-cambered design along with full strength and serviceability checks and vibration design.

For further design assistance call 0800 Roofspec (0800 766 377).

Although the Hibond Design Wizard is a comprehensive design aid, it is intended that the design engineer check, detail and make amendments as necessary in order to approve the design for construction and to ensure compliance with the relevant codes of practice in relation to building.

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3.3.2 DESIGN CONSIDERATIONS *continued*

Composite Beam Design

The use of the composite beam design concept can result in significant strength and stiffness gains over non-composite beam design. Composite beam design uses shear connectors to interconnect the Hibond floor slab and the beam. Shear connectors are typically 19mm diameter x 100mm long nominal.

The shear connection between the Hibond floor slab and the beam resists slipping at the interface, resulting in an interaction between the two members. This allows compressive forces to develop in the Hibond floor slab and tensile forces to develop in the beam.

The strength achieved in the composite beam is generally dependent on the strength of the shear connection provided between the Hibond floor slab and the beam. It is assumed that the shear connection is ductile.

Three types of construction are commonly used with composite beams.

Unpropped
- Where composite slab, secondary and primary beams are all constructed in an unpropped condition.
- Unpropped construction generally uses larger member sizes. However construction time is minimised, and on this basis unpropped construction is preferred.
- The composite slab is poured to level for unpropped construction.

Propped
- Where secondary and primary beams are propped during construction. The composite slab is usually propped but may also be unpropped.
- Propped construction results in more efficient member sizes. However access to sub-trades is restricted until props have been removed.
- The composite slab is poured to level for propped construction.

Pre-cambered
- Where secondary and/or primary beams are fabricated with a pre-camber. The composite slab is unpropped for this type of construction.
- Pre-cambered construction provides member size efficiency and minimal soffit deflection and is effective on large spans.
- Pre-cambered construction requires the composite slab to be poured to constant thickness.

For further and concise information regarding composite beam construction refer to HERA Report R4-107 Composite Floor Construction Handbook.