9.4.2.2 *Orientation of profiled steel sheeting* The orientation of profiled steel sheeting as it affects the perimeter length of Type 1 and Type 3 shear surfaces shall be taken into account as follows (see also Figure 5.2.2.2):

(a) When the acute angle θ between the steel ribs and the longitudinal axis of the steel beam is less than or equal to 15 degrees, the sheeting shall be deemed to be parallel to the beam.

(b) When θ exceeds 15 degrees, the sheeting shall be deemed to be perpendicular to the beam.

9.4.2.3 *Type 1 shear surfaces* At least the following occurrences of Type 1 shear surfaces shall be considered in design (see Figure 9.4.2.3):

(a) At the outside faces of shear connector groups.

(b) Where longitudinal shear reinforcement is curtailed.

(c) Directly over each steel sheeting rib deemed parallel to the steel beam in accordance with Clause 9.4.2.2(a).

The perimeter length of Type 1 shear surfaces shall be assumed to equal one of the following as appropriate:

(i) D_c for solid slabs.

(ii) D_c for composite slabs with sheeting ribs deemed perpendicular to the steel beam.

(iii) $(D_c - h_r)$ directly over ribs for composite slabs with sheeting ribs deemed parallel to the steel beam.

(iv) D_c between ribs for composite slabs with sheeting ribs deemed parallel to the steel beam.

9.4.2.4 *Type 2 shear surfaces* The perimeter length of Type 2 shear surfaces shall be assumed to equal $(b_x + 2h_c)$, where—

b_x = the overall width across the tops of all the shear connectors in the cross-section (see Figure 9.4.1(a)); and

h_c = the overall height of the shear connectors above the top flange of the steel beam.

This is a preview. Click here to purchase the full publication.

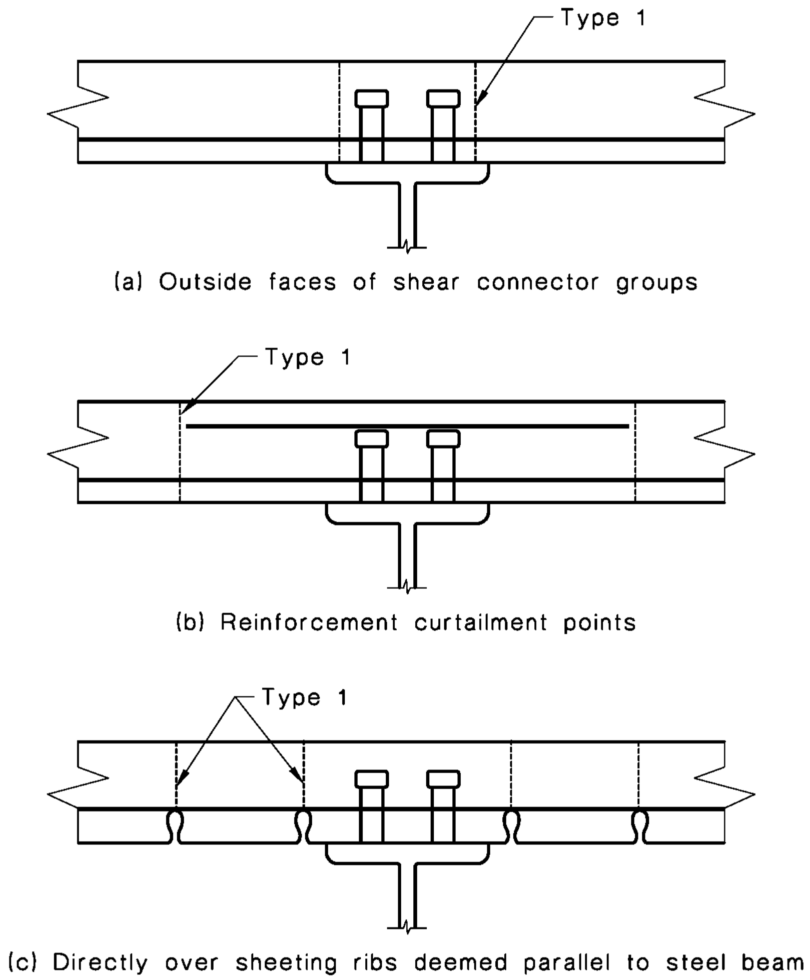
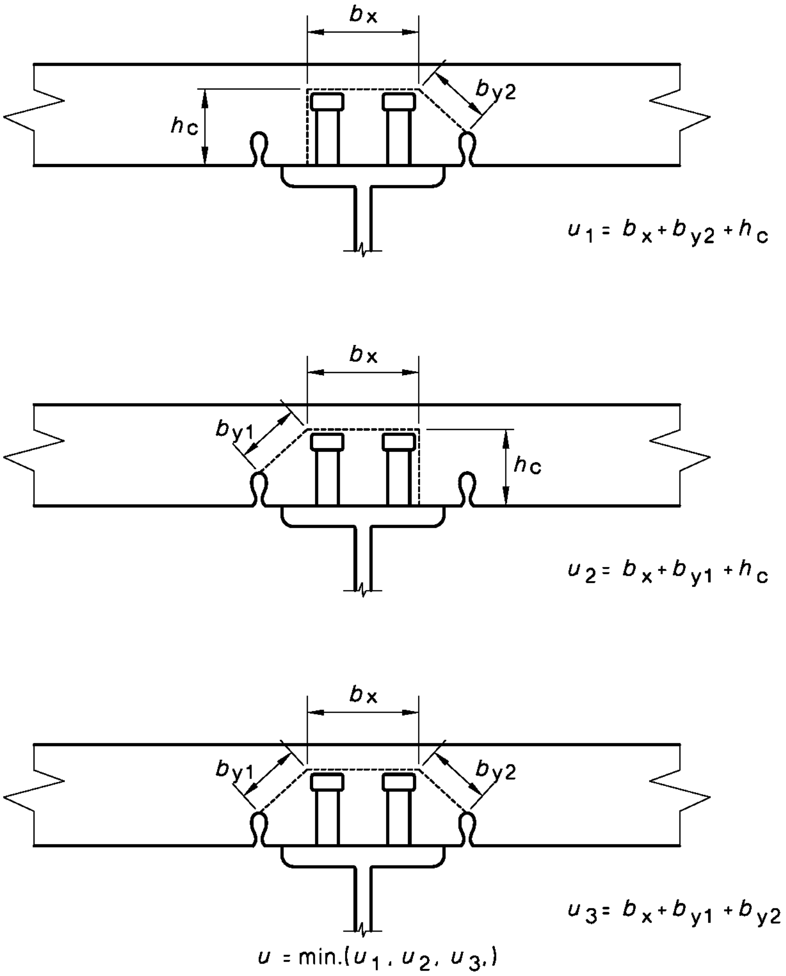


FIGURE 9.4.2.3 LOCATIONS OF TYPE 1 SHEAR SURFACES

This is a preview. Click here to purchase the full publication.

9.4.2.5 *Type 3 shear surfaces* The perimeter length of Type 3 shear surfaces shall be assumed to equal the lesser of the values shown in Figure 9.4.2.5.



NOTE: Reinforcement not shown, for clarity

FIGURE 9.4.2.5 POSSIBLE PERIMETER LENGTHS OF TYPE 3 SHEAR SURFACES

9.5 DESIGN LONGITUDINAL SHEAR FORCE (V^*_L) At a cross-section of a composite beam, the design longitudinal shear force per unit length (V^*_L) shall be assumed to vary linearly from a maximum on each side of the centre-line of the steel beam to zero at the extremities of the effective width of the concrete slab (see Figure 9.5).

Accordingly, the design longitudinal shear force per unit length (V^*_L), acting on a Type 1, shear surface centred distance x from an extremity of the effective width, shall be determined from Equation 9.5(1) and on Types 2 and 3 surfaces from Equation 9.5(2).

$$V^*_L = \left(\frac{x}{b_{cf}}\right) V^*_{L.tot} \qquad \text{. . . 9.5(1)}$$

$$V^*_L = V^*_{L.tot} \qquad \text{. . . 9.5(2)}$$

This is a preview. Click here to purchase the full publication.

9.6 NOMINAL LONGITUDINAL SHEAR CAPACITY (V_L) The nominal longitudinal shear capacity per unit length (V_L) of a Type 1, 2 or 3 shear surface shall be calculated as the lesser value given by the following equations:

(a) $V_L = u(0.36\sqrt{f'_c}) + 0.9A_{sv}\,f_{yr}$ . . . 9.6(1)

(b) $V_L = 0.32\,f'_c\,u$ . . . 9.6(2)

where

u = shear surface perimeter length in millimetres, determined in accordance with Clause 9.4.2

f'_c = characteristic compressive strength of the concrete, in MPa

A_{sv} = total cross-sectional area of longitudinal shear reinforcement crossing the shear surface (see Figure 9.4.1(a)), in mm^2 per mm length of beam

f_{yr} = the yield strength of the longitudinal shear reinforcement, in MPa.

Profiled steel sheeting shall not be considered to contribute to A_{sv}.

NOTE: The units of V_L determined from the above equations are newtons per millimetre length of beam. Designers should ensure that V^*_L and ϕV_L are expressed in the same units when comparing them for the purpose of satisfying Clause 9.3.1.

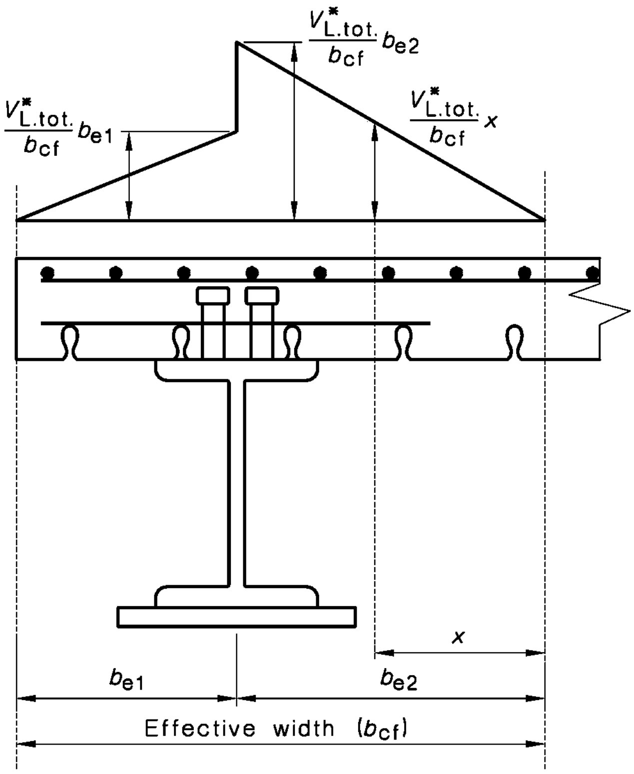


FIGURE 9.5 DISTRIBUTION OF LONGITUDINAL SHEAR FORCE FOR TYPE 1 SHEAR SURFACES

This is a preview. Click here to purchase the full publication.

9.7 TYPE 1, 2 AND 3 LONGITUDINAL SHEAR REINFORCEMENT

9.7.1 General The longitudinal shear reinforcement which crosses a Type 1, 2 or 3 shear surface shall be detailed as follows:

(a) The cross-sectional area per metre length of beam (A_{sv}) shall not be less than that required by Clause 9.3.2, except that for Type 2 and Type 3 shear surfaces, neither shall the area be less than that required by Clause 9.7.2. The reinforcement required for each connector group shall be placed on either or both sides of the connectors of that group within a distance s_c /2 measured along the beam.

(b) It shall be anchored beyond the appropriate sides of the shear surface in accordance with Clause 9.7.3.

(c) Its top face shall be at least 30 mm below the top of the shear connectors in the case of Type 2 and Type 3 shear surfaces (see Figure 9.4.1(a)).

Flexural reinforcement in the slab placed transverse to the longitudinal axis of the beam may be included as part or all of the reinforcement for longitudinal shear transfer, provided that it meets all of these requirements as necessary.

9.7.2 Minimum longitudinal shear reinforcement for Type 2 and 3 shear surfaces The minimum cross-sectional area of longitudinal shear reinforcement required for shear transfer ($A_{sv.min.}$) across Type 2 and 3 shear surfaces, in square millimetres per metre length of beam, shall be calculated according to the following equation:

$$A_{sv.min.} = 800u/(f_{yr}) \qquad \text{. . . 9.7.2(1)}$$

NOTE: The area of bottom bars, $A_{sp.b}$, is required to be not less than $A_{sv.min.}/2$, as indicated in Figure 9.4.1.(a).

9.7.3 Anchorage of longitudinal shear reinforcement Longitudinal shear reinforcement should extend beyond each side of the shear plane for at least the development length for tension ($L_{sy.t}$) determined in accordance with AS 3600. If the distance available for anchorage (L) is less than $L_{sy.t}$, the area of longitudinal shear reinforcement considered to be effective for use in Equation 9.6(1) shall be taken as $A_{sv}L/L_{sy.t}$. In no case shall L be less than 12 d_b for straight deformed bars, where d_b is the nominal diameter of the bar.

9.8 TYPE 4 LONGITUDINAL SHEAR REINFORCEMENT

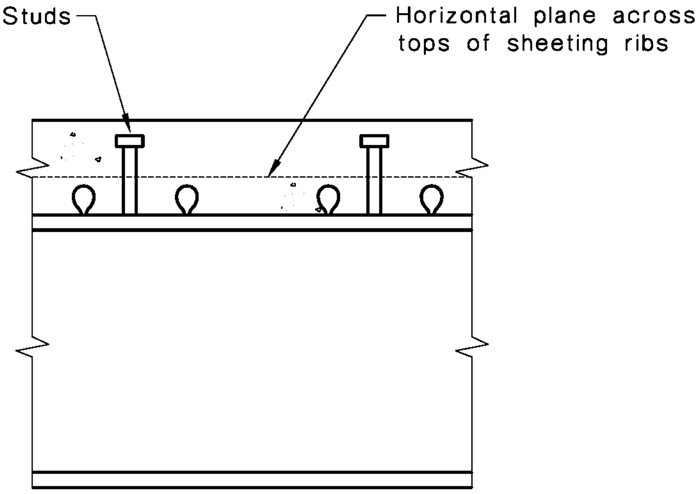
9.8.1 Locations Reinforcement for Type 4 shear surfaces shall be provided in edge beams with profiled steel sheeting deemed perpendicular to the steel beam in accordance with Clause 9.4.2.2 and which extends across the top flange of the steel beam (see Figure 9.4.1(b)), at locations where there are—

(a) two welded stud shear connectors in a sheeting pan, irrespective of the width of the slab outstand; or

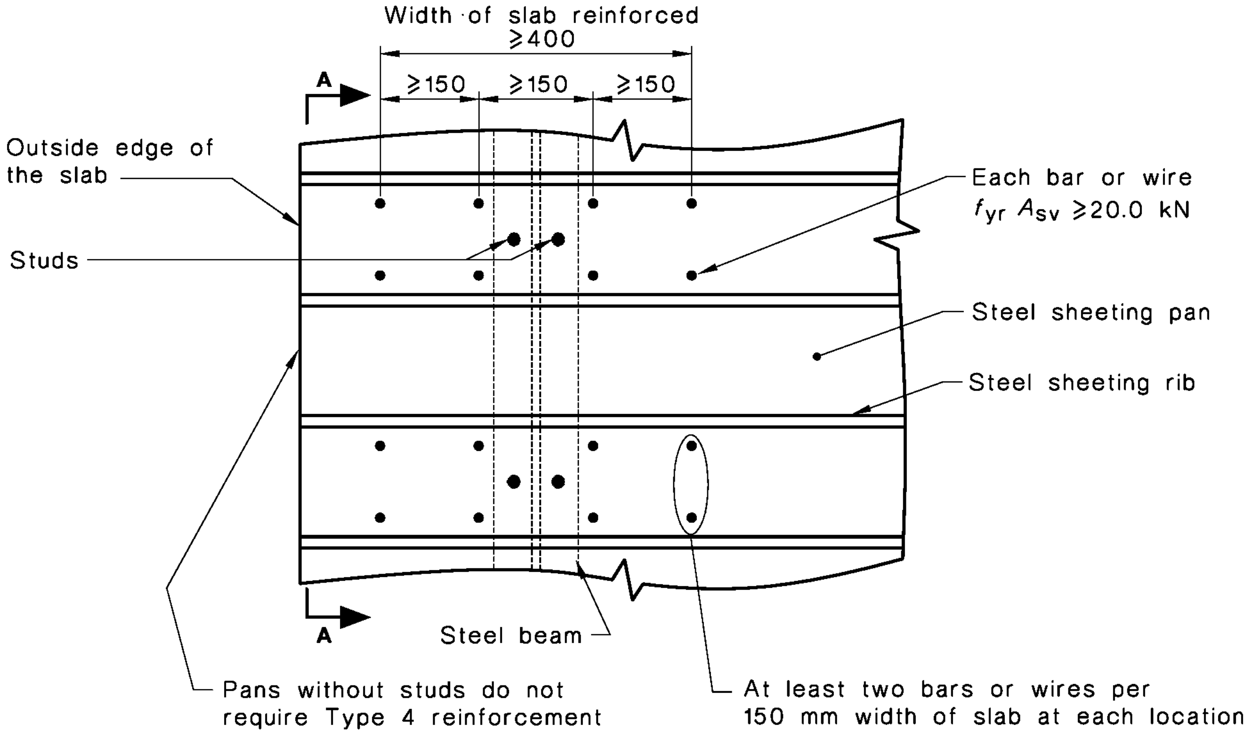
(b) one welded stud shear connector in a sheeting pan, and the slab outstand is less than 600 mm wide measured from the vertical outside edge of the slab to the edge of the nearest shear connector.

9.8.2 Detailing Longitudinal shear reinforcement provided at the locations specified in Clause 9.8.1 and detailed in accordance with the following shall be deemed to develop the required resistance across Type 4 shear surfaces. Alternative detailing may be used provided that it can be demonstrated, by adequate test data, that the alternative prevents this mode of failure.

This is a preview. Click here to purchase the full publication.



(a) Horizontal plane



(b) Plan showing Type 4 reinforcement crossing horizontal plane

FIGURE 9.8.2 TYPE 4 LONGITUDINAL SHEAR REINFORCEMENT

This is a preview. Click here to purchase the full publication.

The reinforcement shall satisfy all of the following:

(a) The reinforcement shall cross the shear surface and be composed of one or more of—

 (i) stirrups or ties, which cross perpendicular to the shear surface and enclose longitudinal bars; and

 (ii) welded-wire fabric, with the longitudinal wires cranked such that they make an angle of between 30 and 90 degrees with the shear surface.

(b) The maximum transverse spacing of consecutive parallel bars or wires which form the stirrups, ties or fabric shall be 150 mm measured perpendicular to the length of the beam (see Figure 9.8.2).

(c) Reinforcement, of nominal tensile capacity ($f_{yr}A_{sv}$) not less than 20 kN per bar or wire, shall be used. At each location, at least two such bars or wires shall cross the shear surface every 150 mm width of slab. The reinforcement shall extend into the top and bottom of the slab above and below the shear surface, respectively, and be adequately anchored to develop a stress of at least $0.5f_{yr}$ in the reinforcement at the level of the shear surface. A width of slab at least equal to 400 mm shall be reinforced. The reinforcement shall be centred over the steel beam, except that when the slab outstand width is too narrow for this to occur, it shall be placed as close to the slab edge as concrete covers will allow.

 NOTE: Detailing of Type 4 longitudinal shear reinforcement is described in Reference 6, Appendix I.

This is a preview. Click here to purchase the full publication.

SECTION 10 DESIGN FOR FIRE RESISTANCE

10.1 REQUIREMENTS This Section applies to composite beams, with either a solid or composite slab, required to have a fire-resistance level (FRL).

For protected composite beams, the thickness of protection material (h_i) shall be not less than that required to attain the period of structural adequacy (PSA) specified by the required FRL.

For unprotected composite beams, the exposed surface area to mass ratio (k_{sm}) shall be not greater than that required to attain the PSA specified by the required FRL.

The period of structural adequacy (PSA) for a composite beam shall be determined in accordance with Clause 10.3.

Connections and web penetrations shall be designed and constructed so that the fire-resistance level of the composite beam is not impaired. This may be achieved by complying with the requirements of Clause 10.9.

10.2 DEFINITIONS For the purpose of this Section, the definitions below apply.

Exposed surface area to mass ratio—the ratio of the surface area exposed to the fire to the mass of steel, noting that in the case of members with fire protection material applied, the exposed surface area is to be taken as the internal surface area of the fire protection material.

Fire exposure condition, either—

(a) *three-sided fire exposure condition*—a composite beam in which the top face of the steel beam is in contact with a solid or composite slab in a specific configuration (see Clause 10.8); or

(b) *four-sided fire exposure condition*—a steel member or element exposed to fire on all sides.

Fire protection system—the fire protection material and its method of attachment to the composite member.

Fire-resistance level (FRL)—the fire-resistance periods for structural adequacy, insulation and integrity, expressed in that order in minutes, which are specified by the Authority for the member or element.

Fire-resistance period—the elapsed time, in minutes, for a prototype member, or element of building construction, to reach the relevant failure criterion specified in AS 1530.4, when tested in accordance with that Standard.

Insulation—the ability of a fire separating member to limit the surface temperature on one side of the member when exposed to fire on the opposite side.

Integrity—the ability of a fire separating member to resist the passage of flames or hot gases through the member when exposed to fire on one side.

Period of structural adequacy (PSA)—the time (t), in minutes, for the member to reach the limit state of structural adequacy.

Prototype—a test specimen representing a member and its fire protection system which is subjected to the Standard Fire Test.

Standard Fire Test—the fire-resistance test specified in AS 1530.4.

Stickability—the ability of the fire protection system to remain in place as the member deflects under load during a fire test, as specified in AS 1530.4.

Structural adequacy—the ability of the member to maintain its structural function when exposed to fire.

This is a preview. Click here to purchase the full publication.

10.3 DETERMINATION OF PERIOD OF STRUCTURAL ADEQUACY The period of structural adequacy (PSA) shall be determined using one of the following methods:

(a) By calculating—

(i) the limiting temperature of the steel (T_l) in accordance with Clause 10.4; and

(ii) the PSA as the time from the start of the test (t) to the time at which the limiting steel temperature is attained in accordance with Clause 10.5 for protected members and Clause 10.6 for unprotected members.

(b) By direct application of a single test in accordance with Clause 10.7.

(c) By other calculation methods as defined in Clause 10.10.

10.4 DETERMINATION OF LIMITING TEMPERATURE OF THE STEEL The limiting temperature of the steel T_l shall be calculated as follows:

$$T_l = 905 - 690\, r_f \qquad \ldots 10.4(1)$$

where

r_f is the maximum value along the length of the beam of the ratio of the design bending moment (M^*), under the design load for fire, to the design moment capacity (ϕM_{bv}) at room temperature.

10.5 DETERMINATION OF TIME AT WHICH LIMITING TEMPERATURE IS ATTAINED FOR PROTECTED MEMBERS

10.5.1 Methods The time (t) at which the limiting temperature (T_l) is attained shall be determined by calculation on the basis of a suitable series of fire tests in accordance with Clause 10.5.2 or from the results of a single test in accordance with Clause 10.5.3.

10.5.2 Temperature based on test series

10.5.2.1 *Method of calculation* Calculation of the variation of steel temperature with time shall be by interpolation of the results of a series of fire tests using the regression analysis equation specified in Clause 10.5.2.2 subject to the limitations and conditions of Clause 10.5.2.3.

10.5.2.2 *Regression analysis* The relationship between temperature (T) and time (t) for a series of tests shall be calculated by least-squares regression as follows:

$$t = k_0 + k_1 h_i + k_2\left(\frac{h_i}{k_{sm}}\right) + k_3 T + k_4 h_i T + k_5\left(\frac{h_i T}{k_{sm}}\right) + k_6\left(\frac{T}{k_{sm}}\right) \qquad \ldots 10.5.2.1(1)$$

where

t = time from the start of the test, in minutes

k_0 to k_6 = regression coefficients

h_i = thickness of fire protection material, in millimetres

T = average steel temperature calculated using all thermocouples as shown in Figure 6.1 of AS 1530.4, in degrees Celsius, $T > 250°C$

k_{sm} = exposed surface area to mass ratio, in square metres per tonne (m^2 /t).

10.5.2.3 *Limitations and conditions on use of regression analysis* Test data to be utilized in accordance with Clause 10.5.2.1 shall satisfy the following:

(a) Tested prototypes shall be protected with board, sprayed, blanket or similar insulation materials having a dry density less than 1000 kg/m^3.

NOTE: There is insufficient test data available to make comprehensive recommendations on interpolation for members protected with other materials such as intumescent coatings.

(b) All prototypes shall be protected with the same fire protection system.

This is a preview. Click here to purchase the full publication.

(c) All prototypes shall have the same fire exposure condition and shall fall within a single group as defined in Clause 10.8.

(d) The test series shall include at least nine tests.

(e) The test series may include prototypes which have not been loaded provided that stickability has been demonstrated.

The steel temperature for a composite beam may be obtained from a regression equation provided that—

(i) the fire protection system is the same as that of the test series;

(ii) the fire exposure condition is the same as that of the test series;

(iii) the temperature can be obtained by interpolation within the window defined by the test series as shown in Figure 10.5.2.2; and

(iv) the data is obtained from either steel or composite member prototypes.

The regression equation obtained for one fire protection system may be applied to another system using the same fire protection material and the same fire exposure condition provided that stickability has been demonstrated for the second system.

A regression equation obtained using prototypes with a four-sided fire exposure condition may be conservatively applied to a composite beam provided that stickability has been demonstrated for the three-sided fire exposure condition.

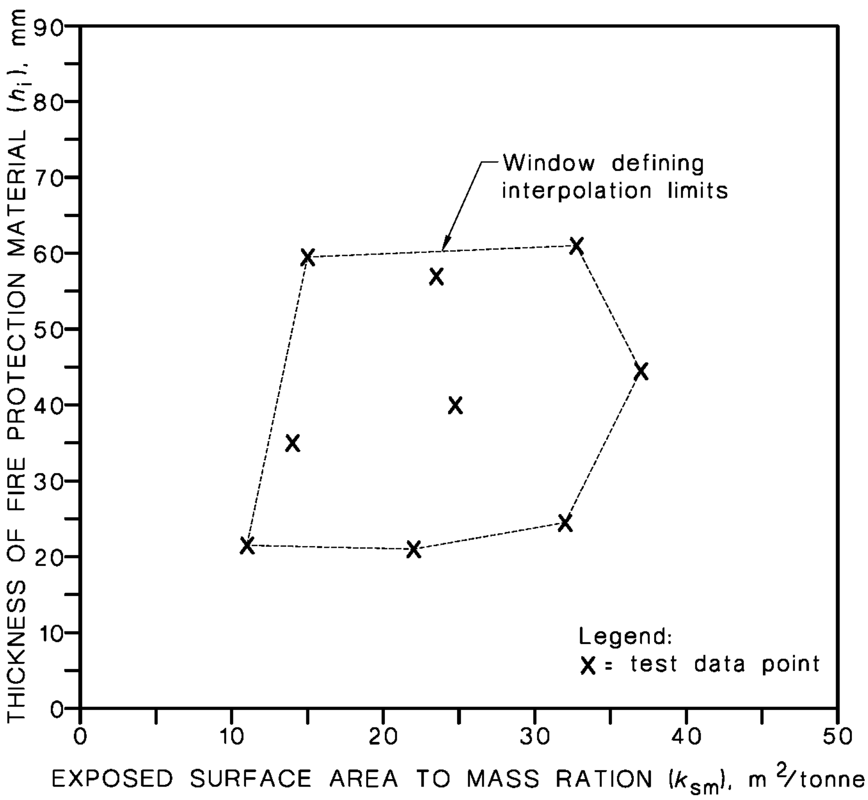


FIGURE 10.5.2.2 DEFINITION OF WINDOW FOR INTERPOLATION LIMITS

This is a preview. Click here to purchase the full publication.