व्यापक परिचालन मसौदा

हमारा संदर्भ : सीईडी 4/टी-71 **17 फरवरी 2015**

तकनीकी समिति : इमारती चूना और जिप्सम उत्पाद विषय समिति, सीईडी 4

प्राप्तकर्ता :

1. **सिविल इंजीनियरी विभाग परिषद् के रूचि रखने वाले सदस्य**
2. **सीईडी 4 के सभी सदस्य**
3. **रूचि रखने वाले अन्य निकाय ।**

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प्रलेख संख्या	**शीर्षक**
सीईडी 4(7987)WC	*भारतीय मानक मसौदा* भवनों के लिए ग्लास फाइबर प्रबलित जिप्सम पैनल के डिजाइन की रीति संहिता

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भारतीय मानक ब्यूरो
BUREAU OF INDIAN STANDARDS

MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG, NEW DELHI 110002

WIDE CIRCULATION DRAFT	Ref	Date
	CED 4/T- 71	17 February 2015

Technical Committee: Building Lime and Gypsum Products Sectional Committee, CED 4

ADDRESSED TO:

1. All Members of Civil Engineering Division Council, CEDC.
2. All Members of CED 4.
3. All other interests.

Dear Sir,

Please find enclosed the following document:

Doc. No.	Title
CED4(7987)WC	Draft Indian Standard for Design of Glass Fibre Reinforced Gypsum (GFRG) Panels for Buildings- Code of Practice

Kindly examine the enclosed drafts and forward your views stating any difficulties which you are likely to experience in your business or profession if they are finally adopted as National Standards/Amendments.

Last date for comments: 18 April 2015

Comments if any may please be made in the format as attached and mailed to the undersigned at the above address. You are requested to send your comments preferably through e-mail to ced@bis.org.in. In case no comments are received or comments received are of editorial in nature, you may kindly permit us to presume your approval for the above document as finalized. However, in case of comments of technical nature are received then it may be finalized either in consultation with the Chairman, Sectional Committee or referred to the Sectional Committee for further necessary action if so desired by the Chairman, Sectional Committee.

The document has also been hosted on BIS website www.bis.org.in.

Thanking you,

Yours faithfully,

(B.K.Sinha)
Head(Civil Engg)
e-mail :ced@bis.org.in
Phone/Fax: 011–2323 5529

Encl: as above

FORMAT FOR SENDING COMMENTS ON THE DOCUMENT

[Please use A4 size sheet of paper only and type within fields indicated. Information in column (3) should include reasons for comments, technical references and suggestions for modified wording of the clause when the existing text is found not acceptable. **Comments through e-mail (ced@bis.org.in/seebait@bis.org.in) shall be appreciated**.]

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Clause/ Table/ Figure No. Commented	Comments/ Modified Wordings	Justification of Proposed Change

BUREAU OF INDIAN STANDARDS

DRAFT FOR COMMENTS ONLY
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DRAFT INDIAN STANDARD FOR DESIGN OF GLASS FIBRE REINFORCED GYPSUM (GFRG) PANELS FOR BUILDINGS- CODE OF PRACTICE

ICS No: **91.060.10; 91.100.10**

Building Lime and Gypsum Products Sectional Committee, CED 4 — Last Date for comments **18 April 2015**

FOREWORD

0.1 Formal clauses of the foreword will be added later

0.2 Glass Fibre Reinforced Gypsum (GFRG) is the name of a new building panel product, made essentially of gypsum plaster, reinforced with glass fibres, and is also known in the industry as Rapidwall (originally invented in Australia). These are manufactured as large light-weight panels, typically 12m long and 3m high, with 124mm thickness and with hollow cavities.

0.3 GFRG panels can be manufactured from various types of gypsum; the use of industrial waste gypsum, which is a waste product of the fertilizer industry, is particularly beneficial from the perspective of sustainability and recycling of waste.

0.4 Use of GFRG panels as walls and floor slabs in buildings, with the cavities filled with concrete or appropriate inert material, contribute significantly to sustainability and 'green building' concept, owing to the resulting savings in the use of high energy-intensive and scarce materials such as cement, steel, sand and water.

0.5 The provisions for structural design of GFRG buildings given in this Code of Practice are based on the GFRG Building Structural Design Manual published by Building Material Technology Promotion Council (BMTPC), Ministry of Housing &Urban Poverty Alleviation, Govt. of India in December, 2013.These design provisions have been based primarily on extensive research carried out at the

Department of Civil Engineering, Indian Institute of Technology Madras. A detailed list of references is given in Appendix B.

0.6 For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis shall be rounded off in accordance with IS 2:1960 'Rules for Rounding off Numerical Values (revised)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Indian Standard

DRAFT CODE OF PRACTICE FOR DESIGN OF GLASS FIBRE REINFORCED GYPSUM (GFRG) PANELS FOR BUILDINGS

1 SCOPE

1.1 This standard provides data on material properties of GFRG panels for use in structural design, as well as the basis for structural design using GFRG panels in building construction.

1.2 This standard covers the structural design of vertical GFRG wall panels in buildings up to a maximum of ten storeys, with the cavities filled with reinforced concrete (partially or wholly), subject to:

a) axial compression

b) compression with out-of-plane bending

c) compression with in-plane bending and shear

1.3 This standard also covers the structural design of GFRG panels used as flexural members in floors and roofs (flat or sloped) and staircases, with the cavities filled with reinforced concrete (partially or wholly).

1.4 These guidelines do not include recommendations for architectural design.

2 REFERENCES

The Indian Standard listed in Annex A contain provisions through reference in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All the standards are subject to revision and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent edition of the standards indicated in Annex A.

3 SYMBOLS

3.1 For the purpose of this standard, the following letter symbols shall have the meaning indicated against each; where other symbols are used, they are explained at the appropriate place.

A = Gross cross-sectional area of panels with cavities

A_c = Net area of cross-section of concrete infill

A_G	=	Net area of cross-section of GFRG panel
a_s	=	Total area of steel bars in a panel
D	=	Depth or width of cross-section
d	=	Effective depth of cross-section
e	=	Eccentricity
E_c	=	Elastic modulus of concrete
E_G	=	Elastic modulus of GFRG
EI	=	Flexural rigidity
f_{ck}	=	Characteristic cube strength of concrete
f_{st}	=	Stress in steel bars
f_y	=	Characteristic strength of steel
M_u	=	Factored bending moment
M_{uc}	=	Out-of-Plane moment capacity, rib parallel to span
$M_{uc\text{-}perp}$	=	Out-of-Plane moment capacity, rib perpendicular to span
M_{ud}	=	Design bending moment capacity
p	=	Percentage of tension steel
P_u	=	Factored axial load
P_{uc}	=	Uni-axial Compressive Strength
P_{ud}	=	Design axial load capacity
R	=	Response reduction factor
t	=	Thickness of panel
T_{uc}	=	Uni-axial Tensile Strength
V_u	=	Factored shear force
V_{uc}	=	Ultimate shear strength
V_{ud}	=	Design shear capacity
x_i	=	Distance from the centre of the panel to the centre of the rebar in each cavity
x_u	=	Depth of compression zone
γ_f	=	Partial safety factor for load
γ_m	=	Partial safety factor for GFRG building panel
γ_s	=	Partial safety factor for reinforcing steel
η	=	Ratio of infilled cavities to total number of cavities

4 GENERAL REQUIREMENTS

4.1 The design shall satisfy the requirements of IS 456, IS 1905, IS 11447, IS 875 (Part 1 to 5), IS 1893 (Part 1), IS 4326 and IS 13920, as applicable.

4.2 "Cutting drawings" shall be prepared with clarity, to facilitate cutting at the manufacturing plant, of the various wall or floor panels to appropriate sizes. In the case of wall panels, openings for doors, windows, etc., shall be suitably marked in the respective panels. When the panels are cut at the factory in accordance with the cutting drawings, the panels shall be suitably marked on the panel surfaces, to facilitate correct identification, for proper placement during erection at the construction site.

4.3 In constructions using GFRG panels as load bearing structural walling, the walls in the ground floor shall be typically founded on reinforced concrete (RC) plinth beams, in which appropriate "starter bars" shall be embedded at the locations where the cavities of the panel are to be filled with RC with appropriate lap length in accordance with IS 456. This ensures connection of the superstructure with the foundation spread over the entire wall length over the network of RC plinth beams, which in turn shall be supported on appropriate foundations, typically comprising spread footings or raft foundations, suitably designed. In the case of multi-storeyed buildings in high seismic zones, the design and detailing shall ensure proper transfer of base shear at the interface of the foundation and superstructure. Shear keys may be provided in the RC plinth beams at the GFRG wall cavity locations, suitably reinforced.

4.4 The cavities in the GFRG panels, used as walls or floors, shall be filled, wherever required structurally, with concrete of grade not less than M20, using aggregate of size less than 12mm. As this concrete is fully encased in the GFRG panel, the exposure condition may be treated as "mild", in accordance with IS 456. Reinforcing bars, of diameters not less than 8mm and of grades recommended in IS 456, shall be embedded in the concrete, in accordance with the structural design.

In GFRG wall panels, cavities shall be normally not kept unfilled, in view of public perception of safety against intrusion, and also facilitate nailing, drilling, fastening of non-structural components etc. It is recommended that this filling be done with the same M20 grade of concrete, although this is not required structurally. However, in the interest of economy, use of low grade concrete (not less than M7.5) or other materials (such as quarry dust filled with 5 percent cement and water to produce a hardened cake), is permitted at such locations.

4.5 It is mandatory to provide RC embedded lintels over openings for doors and windows, exceeding 1.2 m in width.

4.6 Special care shall be taken during construction to ensure proper connections, with concrete filling in the cavities and with appropriate reinforcement detailing, at the junctions between cross walls and at the junctions between vertical walls and floor / roof slabs (in the form of embedded horizontal tie beams), as indicated in Annex C.

4.7 GFRG panels can also be used for the construction of parapets, staircases, lift and balconies, with proper structural design and detailing. If the GFRG panels are used as waist slabs, it is recommended that all the cavities be filled with reinforced concrete. In the case of cantilever projections such as balconies, suitable RC beams (concealed within GFRG forms) may be designed and detailed, as required.

4.8 It is mandatory that special primer specified in the Manual of Waterproofing of GFRG / Rapidwall Structures (2014) be applied on both surfaces of every panel. This shall be done in the factory itself prior to transportation to construction sites, by spraying technique, to all the external and internal wall surfaces and ceilings, before painting.

4.9 It is also mandatory to provide adequate water-proofing treatment for the construction of wall corner joints, RC lintel cum sunshade, external joints between floor/roof slab and walls, parapet wall, wet areas like bath, toilet, balcony, open terrace, roof slab, etc as per the water proofing manual.

5 PRODUCT DIMENSIONS AND PROPERTIES

5.0 The product, Glass Fibre Reinforced Gypsum (GFRG) panel, is a hollow core panel, machine made, using formulated gypsum plaster, mixed with special additives, and reinforced with glass fibre rovings (300-350mm in size), randomly distributed.

5.1 The typical GFRG panel is manufactured to a length of 12.0m, width of 3.0m, and overall thickness of 124 mm, with hollow cavities, as shown in Fig.1. Each 1.0 m segment of the GFRG panel typically comprises four cells, each 250 mm wide and 124 mm thick, containing a cavity, 230 mm x 94 mm as shown in Fig. 2. The various cavities are inter-connected by solid (GFRG) "ribs", 20mm thick, and “flanges”, 15mm thick.

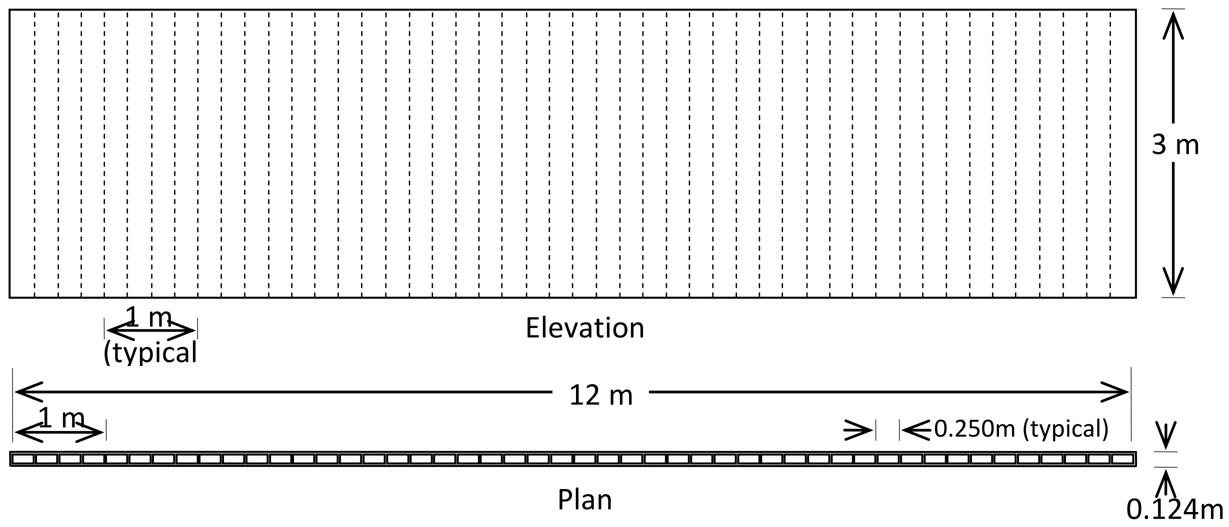


Fig.1 Typical Cross Section of GFRG Panel

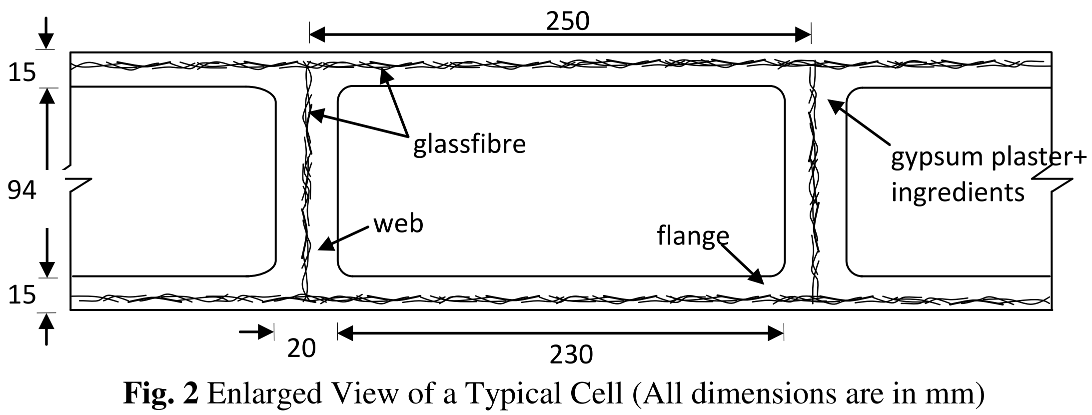


Fig. 2 Enlarged View of a Typical Cell (All dimensions are in mm)

5.1.1 The panels can be cut to required sizes in the factory or at site using appropriate cutting saw.

5.1.2 ***'A' and 'B' sides*****:** The smoother side of the GFRG panel cast against the machine bed in the manufacturing or production process is called 'A' side. The opposite side, is relatively rougher than the 'A' side, and is called the 'B' side of the panel. When the "cutting drawing" is prepared and the panel is cut in the factory to the specified sizes, it is to be assumed that the 'A' side corresponds to the external face of the wall.

5.1.3 Cut edges of the GFRG panel, when used in building construction, should not have the glass fibres exposed (leading to ingress of moisture); these edges shall be suitably encased in concrete and treated with water-proofing.

5.2 The properties of GFRG panels reported in this standard are based on tests carried out on panels with the dimensions shown in Figs 1 and 2, and the design guidelines related to panel strength are based accordingly. If the panels are manufactured to different thicknesses, the properties shall be suitably ascertained by appropriate testing.

Typical mechanical properties of unfilled GFRG panel are given in Table 1.The panels used in construction as load-bearing walls and slabs are expected to comply with the strength and water absorption properties specified here. The characteristic stress-strain curve of GFRG, based on uniaxial compression tests carried out on a prism of size, 250mm high and 520mm wide, is shown in Fig.3 below:

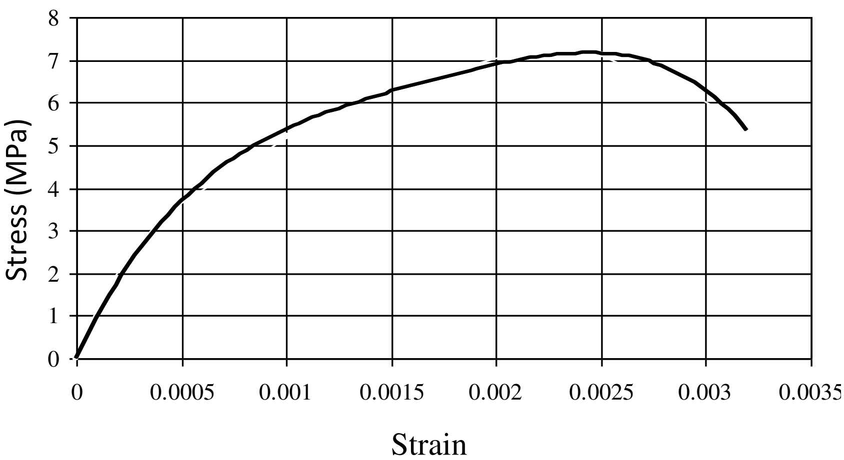


Fig.3 Stress – strain curve of GFRG unfilled prism under compression

The compressive strength, shear strength and fire resistance when the cavities of the panel are filled with M20 grade concrete are given in Table 5.2.

Table 1 Mechanical Properties of GFRG Building Panel (Unfilled)

(Clause 5.2)

Mechanical Property	**Nominal Value**	**Remarks**
Unit weight	0.43kN/m^2	
Modulus of elasticity, E_G	7500 N/mm^2	
Uni-axial compressive strength, P_{uc}	160 kN/m	Strength obtained from longitudinal compression/tension tests with ribs extending in the longitudinal direction
Uni-axial tensile strength, T_{uc}	34 – 37 kN/m	
Ultimate shear strength, V_{uc}	21.6 kN/m	
Out-of-plane moment capacity, Rib parallel to span, M_{uc}	2.1 kNm/m	
Out-of-plane moment capacity, Rib perpendicular to span, $M_{uc\text{-}perp}$	0.88 kNm/m	
Mohr hardness	1.6	
Out-of-plane flexural rigidity, ***EI,*** Rib parallel to span	3.5×10^{11} Nmm^2/m	
Out-of-plane flexural rigidity, ***EI,*** Rib perpendicular to span	1.7×10^{11} Nmm^2/m	
Coefficient of thermal expansion	12×10^{-6}mm/mm/^{o}C	
Water absorption	1.0% :1hr 3.85 % : 24hrs	Average water absorption by weight % after specified hours of immersion
Fire resistance: Structural adequacy/Integrity/Insulation	140/140/140 minutes	IS 3809 : 1979 Fire Resistance for Structures (First Revision)
Sound transmission class (STC)	40 dB	ISO 140-3-1996

Table 2 Mechanical Properties of GFRG Building Panel (filled with minimum M20 grade concrete in all the cavities)
(Clause 5.2)

Property	Nominal Value	Remarks
Uni-axial compressive strength, P_{uc} (Both ends hinged)	1310 kN/m	Obtained from longitudinal compression tests with ribs in the longitudinal direction
Uni-axial compressive strength, P_{uc} (one end fixed and other end hinged)	1360 kN/m	— as above —
Ultimate shear strength, V_{uc}	61 kN/m	Longitudinal cracks (parallel to the ribs)
Fire resistance: Structural adequacy/Integrity/Insulation	241/241/241 minutes	CSIRO, Australia

5.2.1 The nominal value of uni-axial compressive strength and in-plane shear strength of partially infilled GFRG panel with M20 concrete (both ends restrained) may be calculated as follows.

$$P_{uc} = (160 + 1200\eta) \text{ kN/m}$$

$$V_{uc} = (21.6 + 38.4\eta) \text{ kN/m}$$

where η is given by

$$\eta = \frac{\text{Number of concrete filled cavities in the panel}}{\text{Total number of cavities in the panel}}$$

6 DESIGN PHILOSOPHY

6.1 The design capacities given in these guidelines are based on limit states design procedures, considering the ultimate limit state for strength design, treating the 3.0 m high GFRG building panel as the unit material, and considering the strength capacity as obtained from test results. The design should be such that the structure should withstand safely all loads (as per relevant Indian Standards) likely to act on the structure during its lifetime. It shall also satisfy serviceability requirements, such as limitations of deflection and cracking. In general, the structure shall be designed on the basis of the most critical limit state and shall be checked for other limit states.

6.2 Limit States Design

6.2.1 For ensuring the design objectives, the design should be based on the characteristic values of material strengths and applied loads (actions), which take into account the probability of variations in material strength and load. The design values are derived from the characteristic values through the use of partial safety factors, both for material strengths and for loads, for limit states of collapse and serviceability.

6.2.2 Partial Safety Factors for Load, γ_f

The design shall account for various combinations of loads acting on the structure simultaneously. The various load combinations and corresponding partial safety factor for loads shall be used as given in IS 456, summarized in Table3.

Table 3 Values of Partial Safety Factor γ_f for Loads

(Clause 6.2.2)

Load Combination	**Limit State of collapse**			**Limit State of Serviceability**		
	DL	*LL*	*WL/EL*	*DL*	*LL*	*WL/EL*
DL+LL	1.5	1.5	-	1.0	1.0	-
DL+WL/EL	1.5 or 0.9*	-	1.5	1.0	-	1.0
DL+LL+WL/EL	1.2	1.2	1.2	1.0	0.8	0.8

*to be considered when stability against overturning or stress reversal is critical

For the limit state of serviceability, the values of γ_f given in this table are applicable for short-term effects. While assessing long term effects due to creep, the dead load and that part of live load likely to be permanent should be considered.

6.2.3 Partial Safety Factor for Material, γ_m

The magnitude of partial safety factor for the material shall take into account the uncertainty related to the material strength. Although GFRG building panels are manufactured under carefully controlled conditions, it is considered prudent to treat the material like concrete, for which the partial safety factor specified in IS 456 is 1.50. The partial safety factor for the GFRG building panel (with and without concrete infill) shall be taken as γ_m= 1.50in general. The above partial safety factor γ_m= 1.50 is applicable to situations involving out of plane bending where the observed mode of failure is brittle, as well as in plane bending of RC filled GFRG panels where the mode of failure is expected to be ductile.

In the case of reinforcing steel, the partial safety factor shall be taken as $\gamma_s = 1.15$ in all cases, as recommended in IS 456.

While investigating serviceability limit states, the partial safety factor for all materials should be taken as unity.

6.3 Earthquake Resistant Design

6.3.1 Earthquake resistant design shall be carried out in compliance with the requirements of IS 1893 (Part 1). In such design, an important and difficult task is the determination of the response reduction factor (*R*). This is traditionally arrived at, based on the general observed performance of similar buildings during past earthquakes, estimates of general system toughness and the amount of damping present during inelastic response. As the GFRG building constitutes a new type of structure, a reasonable choice of *R* factor can only be made by comparing the GFRG building system with traditional structures, such as reinforced concrete wall building systems for which the response modification factors are already available.

6.3.2 GFRG walls are composite members with partial interaction, and the ductility of a partially interactive member is generally greater than that of a fully interactive reinforced concrete member. In terms of strength reserve, it is recommended that the safety margin adopted for the design of GFRG walls be at least as large as that adopted for concrete structures. Buildings constructed with GFRG walls may be treated as reinforced concrete shear wall structures and to adopt the *R* values from IS 1893(Part 1). Hence, the response reduction factor (*R*) is may be taken as 3.0 for seismic load calculations.

6.4 Design Requirements for Safety Against Progressive Collapse

6.4.1 GFRG buildings shall be designed with proper structural integrity to avoid situations where damage to small areas of a structure or failure of single elements may lead to collapse of major parts of the structure, as recommended in IS 15916: 2010.

The following precaution may generally provide adequate structural integrity:

a) All buildings should be capable of safely resisting the minimum horizontal load of 1.5 percent of characteristic dead load applied at each floor or roof level simultaneously.

b) All buildings shall be provided with effective horizontal ties,

1) around the periphery;

2) internally (in both directions); and

3) to walls.

c) All buildings of five or more storeys shall be provided with vertical ties.

In proportioning the ties, it may be assumed that no other forces are acting and the reinforcement is acting at its characteristic strength.

Normal procedure may be, to design the structure for the usual loads and then carry out a check for the tie forces.

7 AXIAL LOAD CAPACITY

7.1 While assessing the axial load capacity of GFRG building panel (under compression), it is important to consider possible eccentricities in loading. A minimum eccentricity (causing out-of-plane bending) shall always be accounted for in the design.

7.2 Minimum Eccentricity

7.2.1 The design of a GFRG wall panel shall take into account the actual eccentricity of the vertical force, subjected to a minimum value of one-sixth of the wall thickness, $t/6$ (i.e., 20.7mm for$t$ = 124 mm).

7.2.2 Additional value of eccentricity shall be considered when out-of-plane bending is explicitly involved (for example, action of local wind effects on an exposed wall panel).

7.3 Axial Compressive Strength

7.3.1 The characteristic values of axial compressive strength of GFRG panel can be obtained from compression test results of the panel for full height panel, subject to various eccentricities of loading (typically, 20 mm, 30 mm,45 mm) and different boundary conditions; linear interpolation of the results may be assumed. In general, the pinned – pinned condition shall be assumed. For design purposes, the values so obtained should be divided by $\gamma_m = 1.50$.

7.3.2 In the absence of alternate rigorous test data, the values of design strength, P_{ud}, (including partial safety factor), applicable for walls with $t = 124$ mm, shall be taken, as indicated in Cl. 7.3.2.1 for unfilled panels and Cl. 7.3.2.2 for filled panels.

7.3.2.1 ***Unfilled Panels***

The design axial load capacity (P_{ud}), including partial safety factor, of the unfilled GFRG building panel may be found from the following equation for all heights of the walls less than 3.0m (assuming pinned-pinned end conditions).

$$P_{ud} = (68 - 0.9e)$$

where, e is eccentricity in mm and P_{ud} is in kN/m.

7.3.2.2 ***Filled Panels***

The design axial load capacity (P_{ud}), including partial safety factor, of the filled GFRG building panel (filled with minimum M20 grade concrete) may be found from the following equation for all heights of the wall less than 3.0m (assuming pinned-pinned end conditions).

$$P_{ud} = (600 - 13.75e)$$

where, e is eccentricity in mm and P_{ud} is in kN/m.

The contribution of reinforcing bars in compression shall be ignored.

Note: Experimental studies have established that there is no significant enhancement in strength under pure compression due to the presence of rebars, as the failure is caused by buckling of the panel.

8 OUT-OF-PLANE BENDING CAPACITY

8.1 Unfilled GFRG Panels

The out-of-plane design flexural strength of the 124 mm thick GFRG building panel without concrete filling is given in Table 4. The bending capacity depends on the orientation of the ribs, with respect to the direction of bending. Higher capacity is obtained when the ribs are oriented parallel to the span.

Table 4 Out-of-Plane Design Flexural Capacity of Unfilled GFRG Panel

(Clause 8.1)

	Ribs parallel to span	**Ribs perpendicular to span**
Design Moment Capacity, M_{ud}	1.4 kNm/m	0.59 kNm/m

8.2 Filled GFRG Panels

When the cavities are filled with concrete, some enhancement in strength may be expected, provided the ribs are aligned parallel to the span. However, full composite action of GFRG and concrete cannot be mobilized on account of bond slip at the interface. A conservative estimate of the moment capacity can be arrived at by ignoring the contribution of GFRG and considering the action of the concrete beams occupying the cellular cavities (230 mm wide and 94 mm deep), spaced at 250 mm intervals. Accordingly, considering modulus of rupture of concrete as $0.7\sqrt{f_{ck}}$ and applying a partial safety factor of 1.5, the design moment capacity for M20 concrete can be arrived at as M_{ud} = 2.83 kNm/m.

Further enhancement in capacity is possible by embedding and anchoring reinforcing bars in the middle of the cavities, and designing the reinforced concrete beam elements in accordance with requirements of IS 456.

8.3 GFRG Wall Panel Resistance against Wind Loading

The external walls of the building are subjected to wind pressures. The flexural resistance of the GFRG wall panel against such loading shall be checked. One way bending action of the panel (full height of 3m) may be assumed conservatively, with simply supported end conditions and a pressure co-efficient of unity.

9 SHEAR STRENGTH

9.1 The unit shear strength capacity of the 124 mm thick, 3.0 m high GFRG panel is given in Table 5. The ultimate design shear strength of a GFRG panel is given by the unit shear capacity in Table 5 multiplied by the length of the panel.

Table 5 Shear Strength of GFRG Panel as Vertical Walls
(Clause 9.1)

Application	**Design Shear Capacity, V_{ud} (kN/m)**
Unfilled GFRG panel	14.4
GFRG panel filled with 20 MPa concrete	40.0
GFRG panel partially filled with 20 MPa concrete	$14.4 + 25.6\eta$

9.2 In a multi-storeyed construction, using GFRG wall panels as load bearing construction, different walls will be subjected to different shear forces, at any storey level under consideration. Longer walls, which are stiffer, will attract more lateral shear. The maximum length of an individual shear wall segment may be limited to 3.5m in the finite element model used for analysis under factored loads. The average value of factored shear force calculated for all walls in any one direction at any storey level shall not exceed the value indicated in Table 5. In a few walls, some local increase (up to 20 percent) in shear capacity may be permitted, provided the average value for all walls (combined) is within the prescribed limit. Double walls may be provided, if there is a higher demand for shear strength.

9.3 In wall construction for multi-storeyed buildings, all cavities shall be filled with concrete (of grade not less than M20) and reinforced appropriately. The design of such reinforcement is covered in Section 9. The rebars shall be provided for the full height in the cavities of the concrete-filled GFRG panels, and appropriately lapped (with lap lengths as specified in IS 456) wherever required. At the interface with the foundation plinth beam, starter bars should be provided in each cell embedded in concrete (of strength not less than 20 MPa) for a height of not less than 450 mm. In the case of tall buildings, where high base shear is expected to be transmitted, it is desirable to provide appropriate keys in the plinth beam to provide for improved shear transfer.

10 IN-PLANE BENDING CAPACITY

10.1 General

10.1.1GFRG panels can be used not only as load bearing walls, but also as walls transferring lateral loads, resisting axial force (P), lateral in-plane shear force (V) and in-plane bending moment (M). Such wall panels shall be filled with concrete and reinforced with steel.

10.1.2 The in-plane bending capacity of the walls depends on its length, the reinforcement provided, as well as the level of axial load and lateral shear. The design in-plane bending capacity (M_{ud}) and its relationship with the design axial load capacity (P_{ud}) is usually described by means of a P_{ud} - M_{ud} interaction diagram (See10.2). The values of M_{ud} increase with the length of the wall. However, experimental studies of GFRG panels subjected to lateral loading have shown that failure is initiated by vertical cracking caused by shear failure of the GFRG skin. Following such vertical cracking, the wall segments separated by the vertical cracks tend to behave independently, although their deformations at the top and bottom are governed by the corresponding deformations in the connecting floor diaphragm. Hence, for all practical purposes, the in-plane bending capacity is limited by the corresponding shear capacity. Longer shear walls tend to attract larger lateral loads and will form vertical shear cracks in the middle region, causing a further redistribution of forces, and possible further vertical shear cracking.

Hence, under factored lateral loads (earthquake or wind), it is recommended that in the finite element model, the long walls are suitably segmented such that no segment exceeds 3.5m in length. Also, while modelling, care should be taken to consider T, L and I shaped flanged sections as being made up of separate rectangular segments with no shear transfer between them.

Tests have shown that providing two vertical bars in each cavity generates improved performance than a single bar. Axial load – moment interaction diagrams (design charts), for various wall lengths, varying from 1.0 m to 3.5m with increments of 0.25 m, for various bar diameters (8 to 18 mm) of Fe 415 and Fe 500 grade steel, M20 and M25 grade concrete, are given for convenient use in the design office. These charts are given in Annex B.

For low rise GFRG buildings (up to three storeys), all cavities need not be infilled with reinforced concrete, although it is desirable to fill all cavities with plain concrete. Reinforcing bars may be provided where required, but in no case, more than three adjoining cavities shall remain unreinforced. Single bar reinforcement of suitable diameter may be used in such low-rise buildings. Design interaction curves of GFRG panels partially/fully infilled with concrete and reinforced with a single bar are also given in Annex B.

10.2 Basic Design Procedure for generating P_{ud}- M_{ud} Interaction Diagram

10.2.1 Generation of the interaction diagram of a typical GFRG building panel is based on a simplified procedure, which is a modified version of the 'lower bound solution', originally proposed by Wu (2009). Certain assumptions are made to develop the approximate interaction curve from the principles of mechanics.

10.2.2 The cross section of a typical GFRG panel infilled with concrete and reinforcement bars in each cell is shown in Fig. 3a. The behaviour of the GFRG panel infilled with concrete depends on the bond between the concrete and the GFRG panel. This is reflected in the variation of normal strain (in the vertical direction) along the length of the wall, as shown in Fig. 3. If there is no bond, there would not be any interaction between them, resulting in small strain with multiple neutral axes, as shown in Fig. 3b. If it is assumed that the concrete cores are fully bonded to the GFRG panel, then the "plane section remain plane" assumption is valid for the entire section and the strain profile will be a straight line with a single neutral axis, as shown in Fig. 3c. This behaviour is similar to a reinforced concrete flexural wall. However, the limited bond between the concrete cores and the GFRG panel is difficult to quantify. The probable strain profile is likely to be as shown in Fig.3d. A linear 'lower bound' assumption of strain profile can be assumed with the ultimate compressive strain (ε_{cu}), as shown in Fig. 3d. The value of ε_{cu} is limited by the out-of plane buckling strength of the panel and includes enhancement due to strain gradient for short wall lengths.

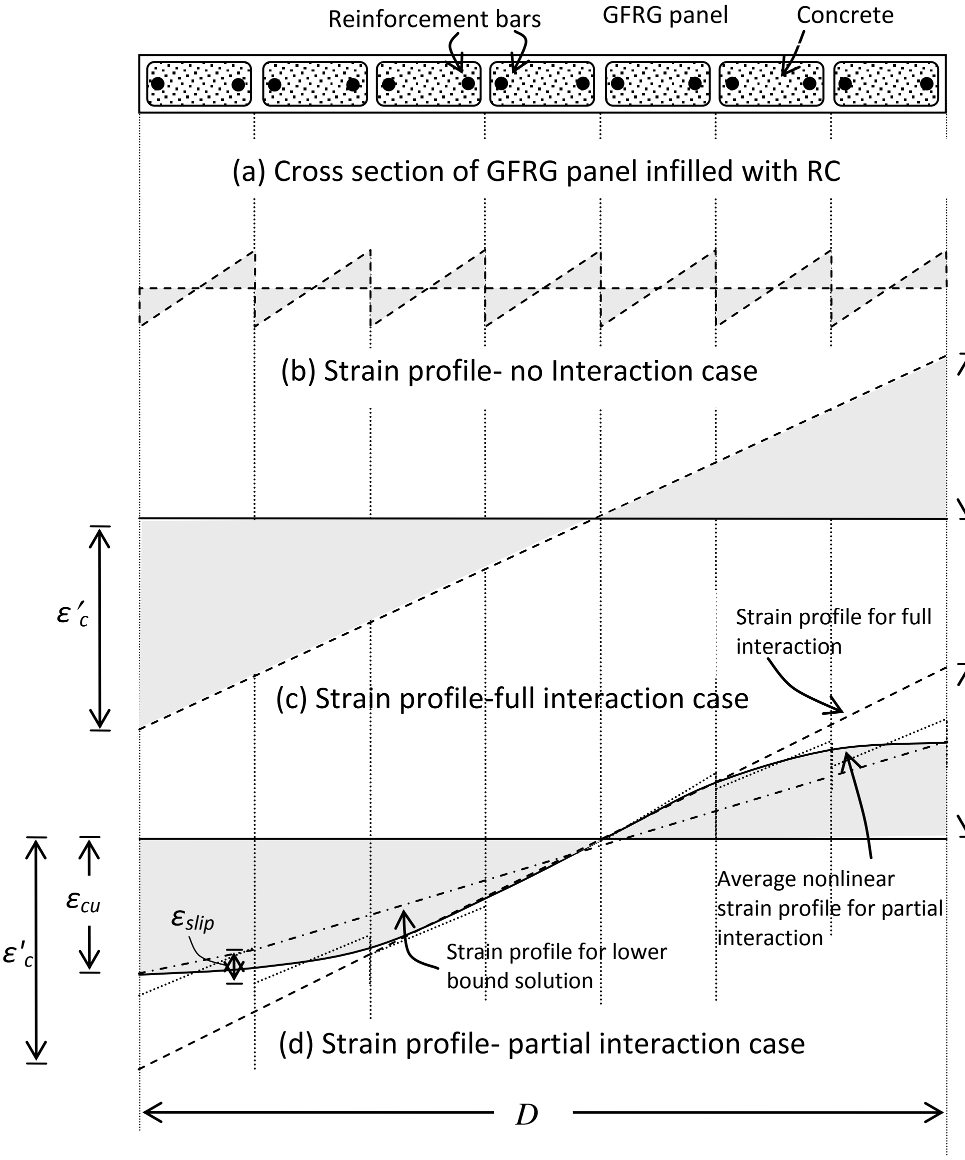


Fig. 3 Strain Profiles for Nil, Full and Partial Interaction between GFRG panel and Concrete

10.2.3 Distribution of Strain at Ultimate limit state

Fig. 4 depicts how the value ε_{cu} is to be computed depending on the location of the neutral axis x_u (from the extreme compression location), which in turn depends on the eccentricity of loading, $e = M_{ud} / P_{ud}$

Case 1: Pure compression **($x_u \to \infty$)**

Under pure compression, ($e \to 0,\ x_u \to \infty$), ε_{cu} is limited to:

$$\varepsilon_{c0} = \frac{p}{E}$$

where p is the compressive stress of the wall at the axial buckling load (to be taken as 1360/1.5 = 907 kN/m, refer table 2) and E is the effective Young's modulus of the composite wall given by

$$E = \frac{E_C A_C + E_G A_G}{A_C + A_G}$$

where A_C and A_G are the areas of the concrete and the GFRG panel, respectively; and $E_c = 5000\sqrt{f_{ck}}$ (in MPa) and E_G are the values of elastic modulus of concrete and the GFRG panel (refer table 1) respectively. Typical values of E using M20 and M25 grades of concrete are 17860 MPa and 19500 MPa respectively.

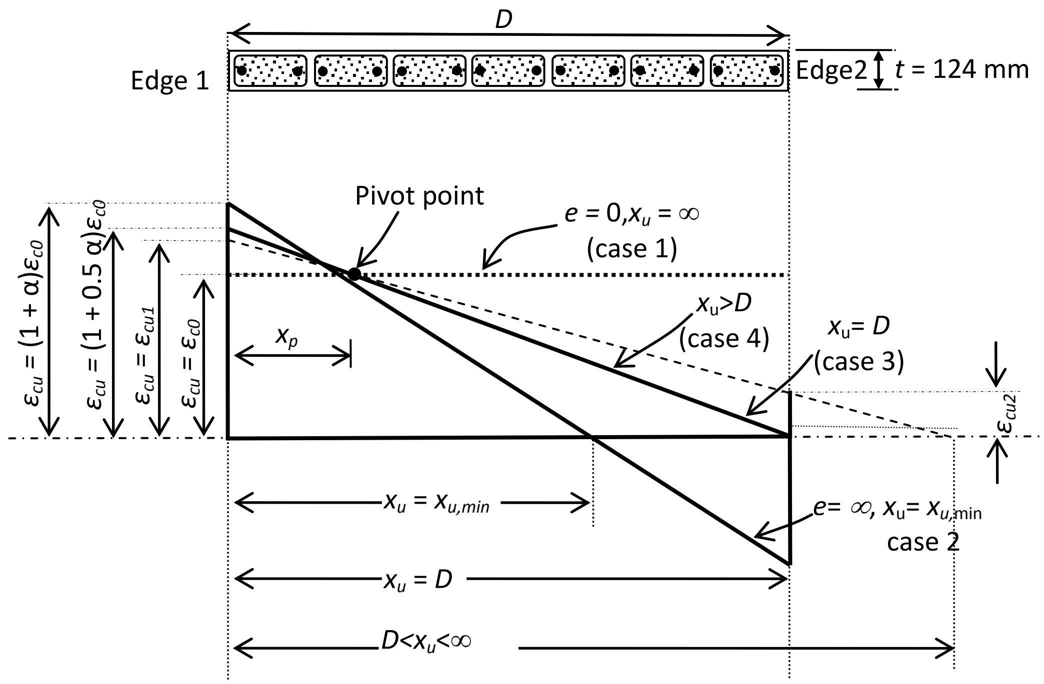


Fig. 4 Recommended strain profile for design

Case 2: Pure bending ($x_u = x_{u,\min}$)

For the extreme case of pure in-plane bending ($e \to \infty,\ x_u = x_{u,\min}$), an enhancement over ε_{c0} is proposed as follows:

$$\varepsilon_{cu} = \varepsilon_{c0}\left(1+\alpha\right)$$

where, $$\alpha = \begin{cases} 0.8\left(2-D\right) & : \text{ for } 1 \le D \le 2.0\,\text{m} \\ 0 & : \text{ for } D > 2.0\text{m} \end{cases}$$

***Case 3: Neutral axis at edge of section* (x_u= *D*)**

For the case, $x_u = D$, the value of ε_{cu} shall be taken as:

$$\varepsilon_{cu} = \varepsilon_{c0}\left(1+0.5\alpha\right)$$

***Case 4: Neutral axis outside section* (x_u>*D*)**

When the neutral axis lies outside the section $\left(x_u > D\right)$, the maximum compressive strain $\varepsilon_{cu} = \varepsilon_{cu1}$ can be calculated by linear interpolation. The point of intersection of the two limiting strain profiles, corresponding to $x_u = D$ and $x_u = \infty$, acts like a 'pivot' point through which all strain profiles pass when $x_u > D$, as shown in Fig. 4. The values of the maximum compressive strain at edge 1, ε_{cu1}, and strain at edge 2, $\varepsilon_{cu2}$are accordingly given by:

$$\varepsilon_{cu1} = \frac{\varepsilon_{c0}}{(1-x_p/x_u)} \qquad \text{for} x_u > D$$

$$\varepsilon_{cu2} = \frac{\varepsilon_{cu1}(x_u - D)}{x_u} \qquad \text{for} x_u > D$$

where, $x_p = D\left(1 - \frac{1}{1+0.5\alpha}\right)$

***Case 5: Neutral axis inside section* (x_u<*D*)**

When the neutral axis lies inside the section ($x_u < D$), linear interpolation shall be done to obtain the value of ε_{cu}:

$$\varepsilon_{cu} = \varepsilon_{c0}\left[1+0.5\alpha\left(1+\frac{D-x_u}{D-x_{u,\min}}\right)\right] \quad \text{for } x_{u,\min} < x_u < D$$

10.3 Generation of Design Interaction Curve

10.3.1 A typical interaction diagram, with critical points marked, is shown in Fig.5. The design strength of a wall panel subject to in-plane moment (M_{ud}) and axial load (P_{ud}), with eccentricity, $e = M_{ud}/P_{ud}$, comprises values of P_{ud} and M_{ud} (corresponding to $0 < e < \infty$), all of which can be described by a single curve, termed as design interaction curve. The analysis for design strength basically entails two conditions: strain compatibility and force equilibrium.

Point A: Pure compression: $e = 0$, $x_u \rightarrow \infty$

$$P_{ud} = p\,D\,t \text{ kN/m}; \qquad M_{ud} = 0 \text{ kNm/m}$$

where D is in m.

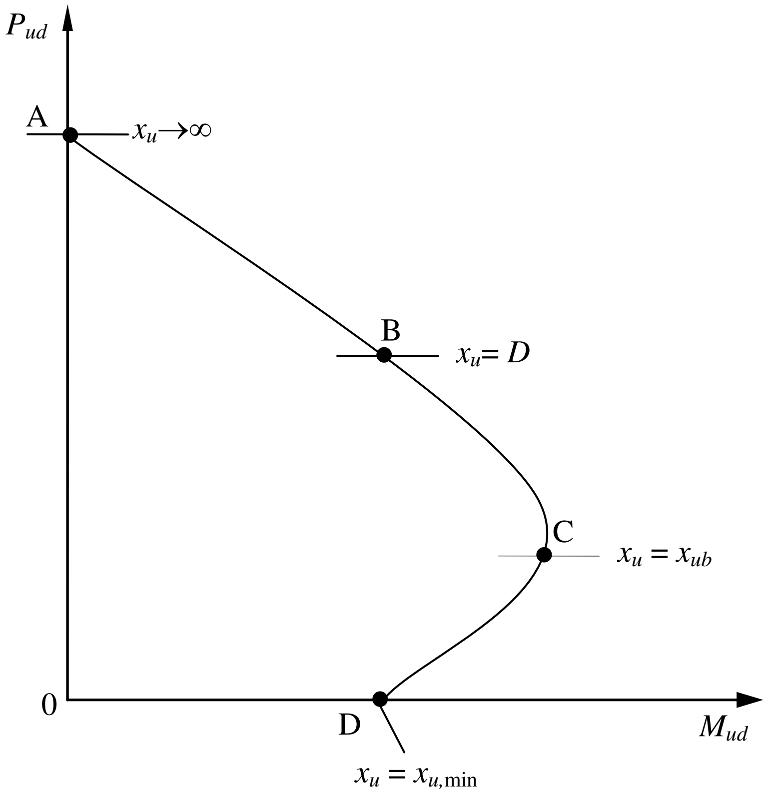


Fig.5 Typical $P_u - M_u$ interaction curve

Between points A and B: $x_u > D$

$$P_{ud} = \left(\frac{\varepsilon_{cu1} + \varepsilon_{cu2}}{2}\right) E\,D\,t$$

$$M_{ud} = P_{ud}\left(\frac{D}{2} \quad \bar{x}_1\right)$$

where $\bar{x}_1$ is the centroid of the compressive force from the edge 1 given by

where, $\bar{x}_1 = \dfrac{D}{3}\dfrac{(2\varepsilon_{cu2} + \varepsilon_{cu1})}{(\varepsilon_{cu1} + \varepsilon_{cu2})}$

***Between points B and C*:** $x_{ub} \leq x_u < D$

where x_{ub} is the neutral axis depth corresponding to balancing point when the strain in the steel (ε_t) reaches its yield strain (ε_y). The corresponding strain and stress variation across the panel width is shown in Fig. 6.

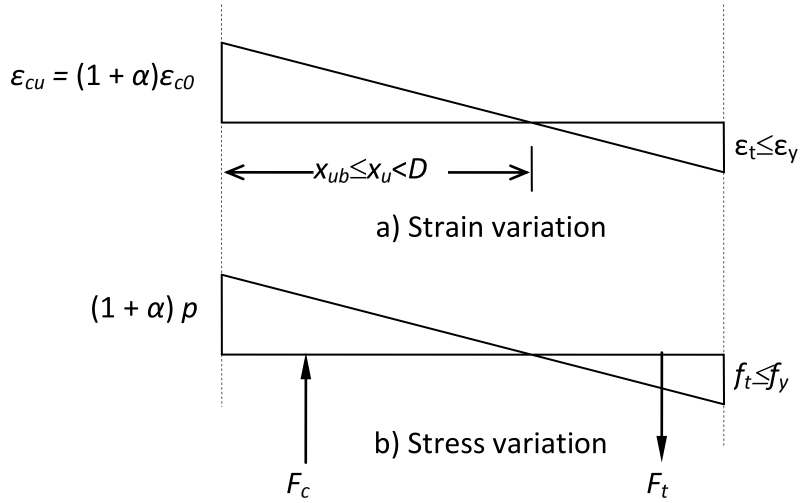


Fig. 6 Stress and strain variation across cross section

The resultant compressive force (F_c), the resultant tensile fore (F_t), the values of P_{ud} and M_{ud} can be calculated from the Fig. 6, as follows.

$$F_c = \frac{(1+\alpha)\, p\, t\, x_u}{2}$$

$$F_t = \varepsilon_t E_s a_s \frac{(D - x_u)}{2}$$

$$P_{ud} = F_c - F_t$$

$$M_{ud} = F_c\left(\frac{D}{2} - \frac{x_u}{3}\right) + F_t\left(\frac{D}{2} - \frac{D - x_u}{3}\right)$$

where, a_s is area of reinforcement per unit length.

***Between points C and D*:** $x_{u,\min} \leq x_u < x_{ub}$

The corresponding strain and stress variation across the panel width is shown in Fig.9.4.

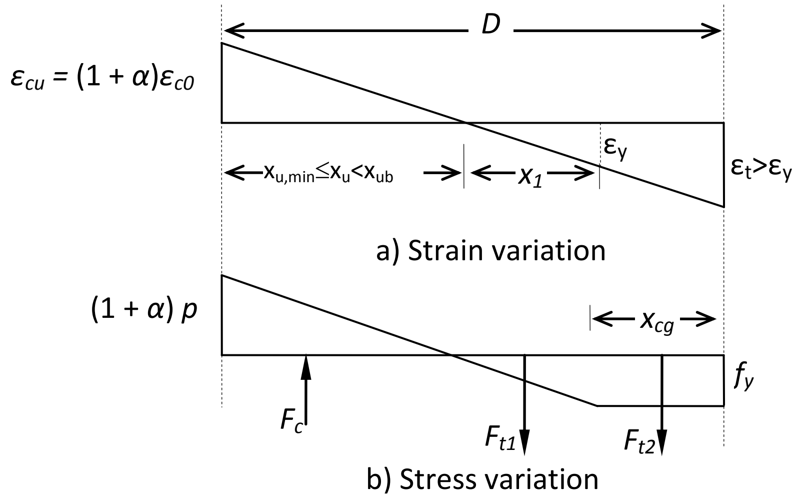


Fig. 7 Stress and strain variation across cross section after steel yields

The resultant compressive force (F_c), the resultant tensile force (F_t), and the values of P_{uc} and M_{uc} can be calculated from Fig.7, as follows:

$$F_c = \frac{(1+\alpha)\, p\, t\, x_u}{2}$$

$$F_{t1} = 0.5 f_y\, a_s\, x_1$$

where,
$$x_1 = \frac{\varepsilon_y x_u}{\varepsilon_{cu}}$$

$$F_{t2} = f_y a_s (D - x_u - x_1)$$

$$F_t = F_{t1} + F_{t2}$$

$$P_{ud} = F_c - F_t$$

$$M_{ud} = F_c\left(\frac{D}{2} - \frac{x_u}{3}\right) + F_t\left(\frac{D}{2} - x_{cg}\right)$$

where x_{cg} is the distance from the right side of the panel, as shown in Fig.7, through which the resultant of forces $F_{t1}$and F_{t2}acts.

11 DESIGN OF FLOOR/ROOF SLAB

11.1 GFRG panels, with ribs aligned in the direction of bending, can be designed as a one-way slab system, with the cavities suitably reinforced, as shown in Fig. 8.

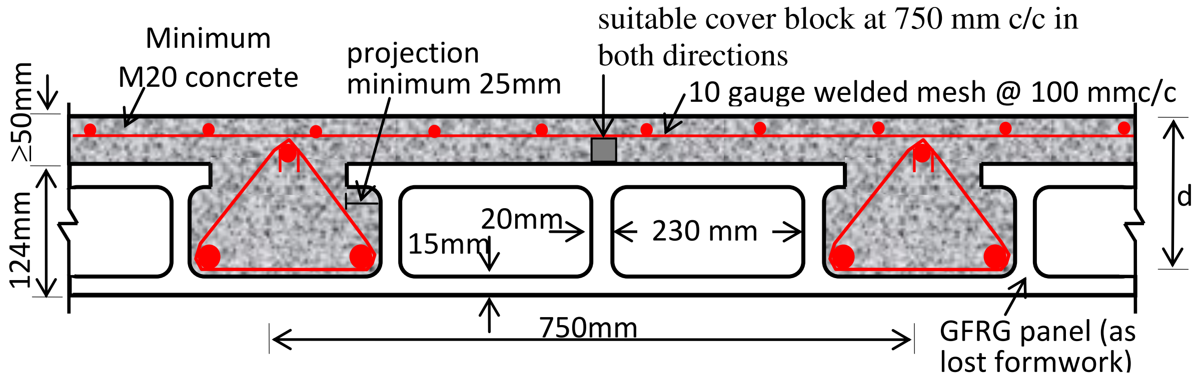


Fig. 8 Typical cross-section of GFRG-RC composite slab (with concealed RC beams)

11.2 GFRG-RC composite slab systems may be used efficiently in floor slabs and roof slabs. The ribs should be oriented along the shorter span, supported on GFRG wall panels. Although this is a composite system comprising GFRG panel and cast insitu reinforced concrete, for convenience in design, the contribution of GFRG panel towards the flexural strength may be ignored and the GFRG panel can be treated as lost formwork. RC concealed beams, provided by filling cavities at regular intervals (typically, every third cavity or every alternate cavity, if required) and suitably reinforced, combined with a screed concrete of thickness not less than 50 mm, as shown in Fig.8, provide a flanged-beam action. One way slab action may be assumed for strength and deflection check, considering T beam action of the embedded beams. In the screed concrete, suitable welded wire fabric (of required gauge and spacing) shall be provided. The design of reinforcement in the concealed beams shall conform to the requirements of IS 456. Such slabs can be conveniently designed up to spans of 5m. For commercial or public buildings with high live load, the maximum clear span may be limited to 4m.

11.3 For floor/roof slab with larger spans and/or high imposed loads, or in balconies, etc., one or more intermediate supporting RC beams may be provided (concealed inside GFRG forms), with sufficient depth protruding below the soffit of the GFRG-RC composite slab (typically 124mm below), in a direction perpendicular to the ribs in the GFRG panel. The RC beam shall be suitably designed and detailed, as indicated in Fig. 9, in accordance with IS 456.

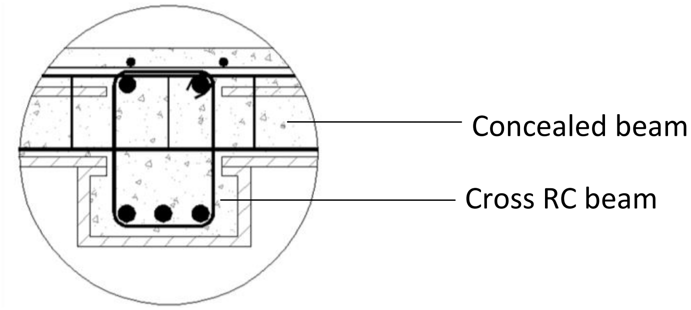


Fig. 9 GFRG-RC composite intermediate beam (where required)

11.4 When the top flange of a cavity of the panel is cut longitudinally(for providing the embedded beam), it must be ensured that the cut flanges shall project 25mm on either side, as shown in Fig. 8 and Fig. 9, to ensure proper integrity of the composite system.

11.5 For roof slab, minimum of 60 mm thick screed concrete shall be provided. Special care shall be taken while concreting the roof slab, to ensure proper compaction and to render the concrete impermeable.

11.6 Clear cover, not less than 15mm, shall be provided to all reinforcement adjoining GFRG side and bottom forms, in the composite GFRG-RC slab and beam system.

11.7 In GFRG floor and roof slabs, when the clear span (in the direction of the ribs) exceeds 2.92m, jointing of the GFRG panel shall be treated as described in Annex-C (clause C-12).

12 GFRG Building Panel as Pitched (Sloped) Roofing Element

12.1 Unfilled GFRG panels can be used as pitched roofs for single storeyed small span buildings, which is commonly adopted for low income group housing. Some nominal filling with reinforcement may be done at eaves and ridge locations, as shown in Fig.10.

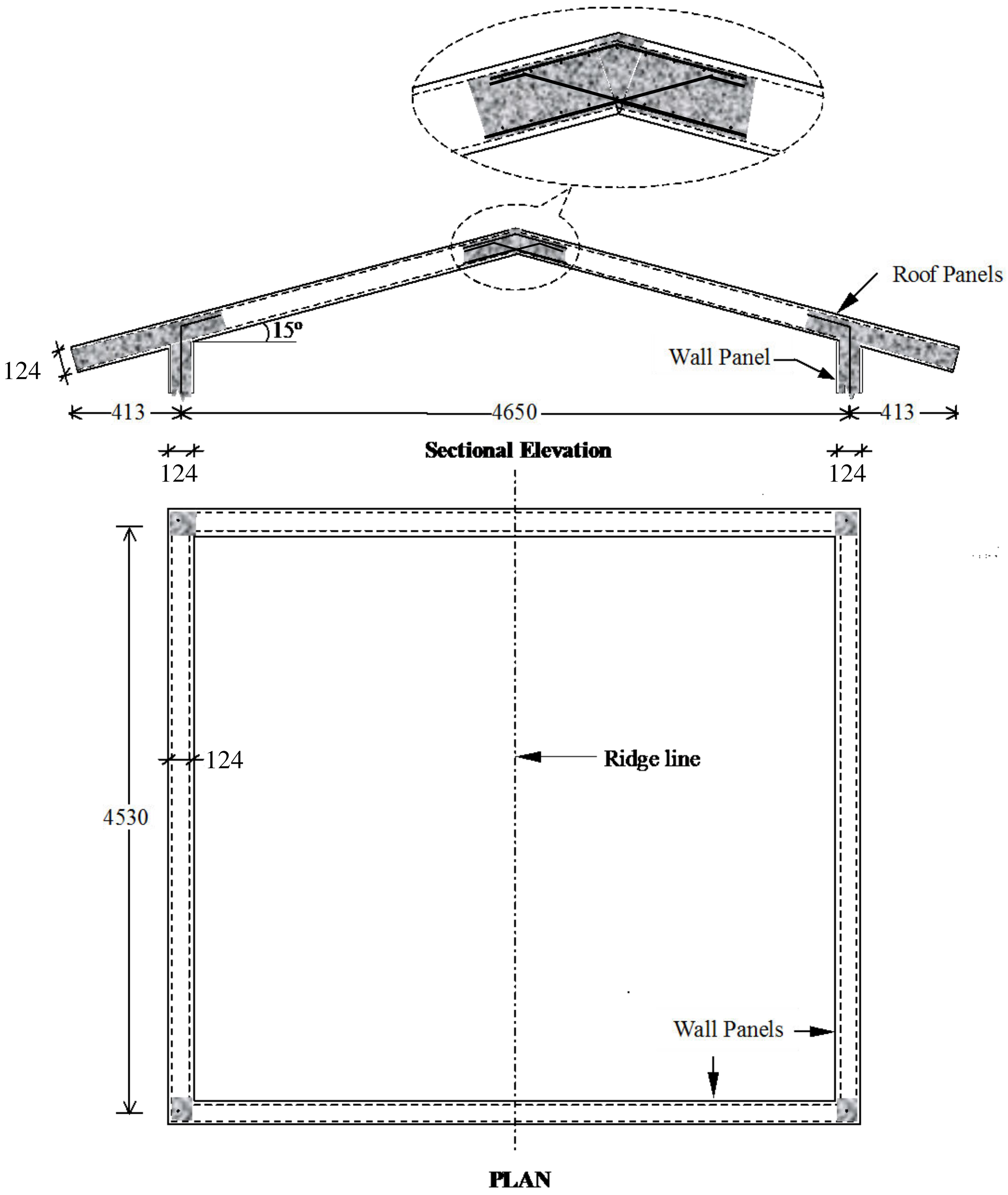


Fig. 10 Typical unfilled GFRG pitched roof

ANNEX A

(Clause 2)

LIST OF REFERRED INDIAN STANDARDS

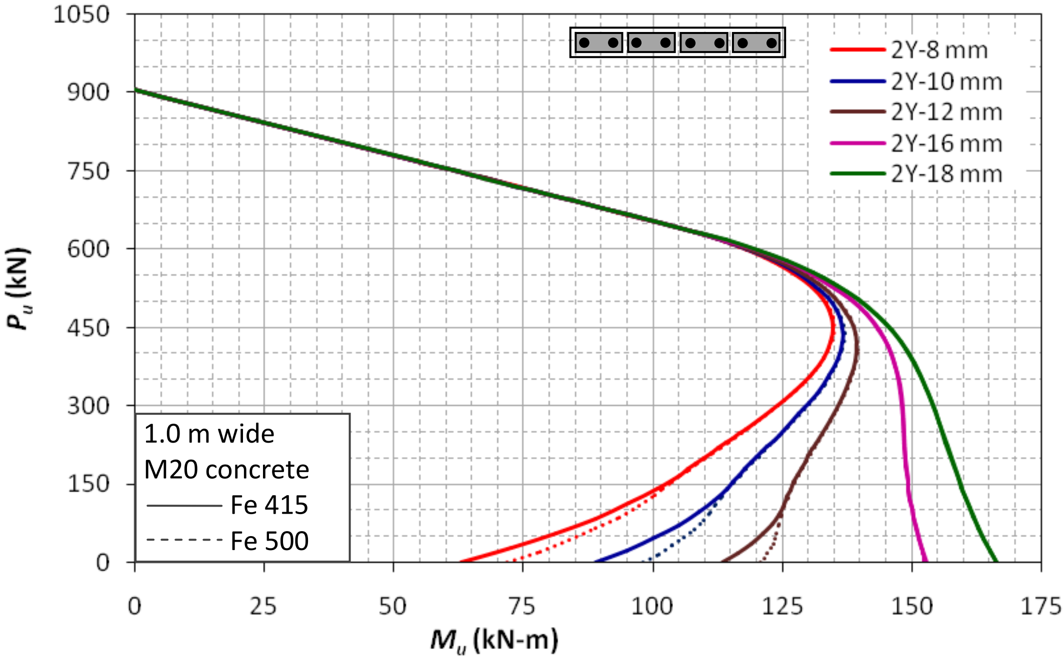
IS NO	*Title*
456 :2000	Code of practice for plain and reinforced Concrete(*Fourth Revision*)
875(Part1):1987	Code of practice for design loads(other than earthquakes) for buildings and structures Part1 Dead Loads-Unit weight of building materials and stored materials(*second revision*)
875(Part2):1987	Code of practice for design loads(other than earthquakes) for buildings and structures Part2 Imposed loads(*second revision*)
875(Part3):1987	Code of practice for design loads(other than earthquakes) for buildings and structures Part 3 wind loads (*second revision*)
875(Part4):1987	Code of practice for design loads(other than earthquakes) for buildings and structures Part 4 snow loads (*second revision*)
875(Part5):1987	Code of practice for design loads(other than earthquakes) for buildings and structures Part 5 special loads (*second revision*)
1905:1987	Code of practice for structural use of unreinforced masonry, Bureau of Indian Standards, New Delhi.
1893(Part1):2002	Criteria for earthquake resistant design of structures Part1 General provisions for

	buildings *(first revision)*
4326:1993	Code of practice for earthquake design and construction of buildings(second revision)
13920:1993	Code of practice for ductile detailing of reinforced concrete structures subjected to seismic loads
IS 15916: 2010	Code of Practice for Building Design and Erection using Prefabricated Concrete

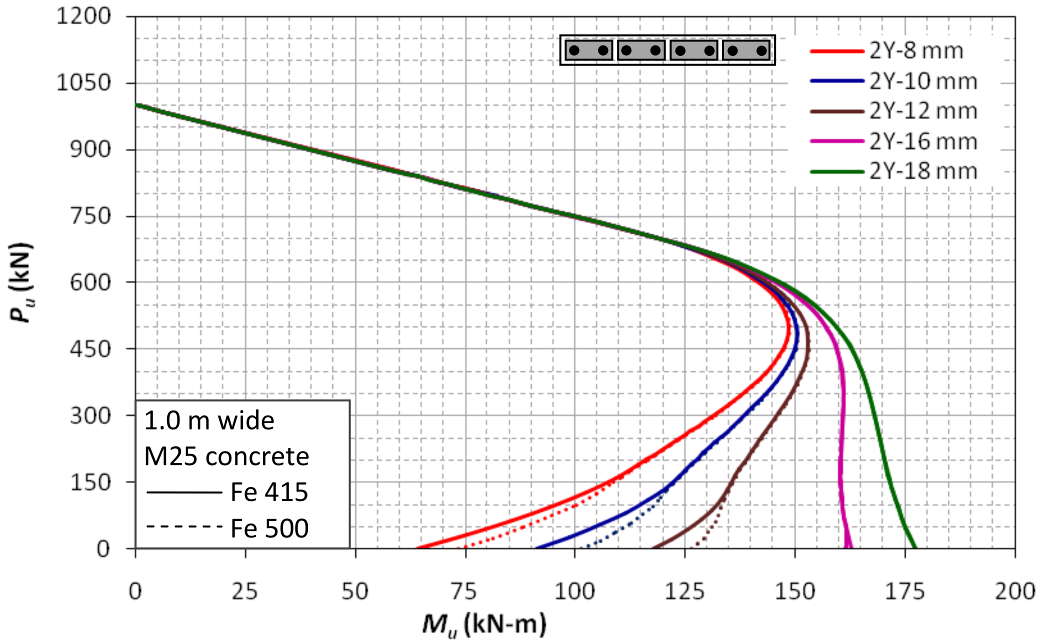
ANNEX B

(Clause 10.1.2)

DESIGN P_{UD} - M_{UD} INTERACTION DIAGRAMS

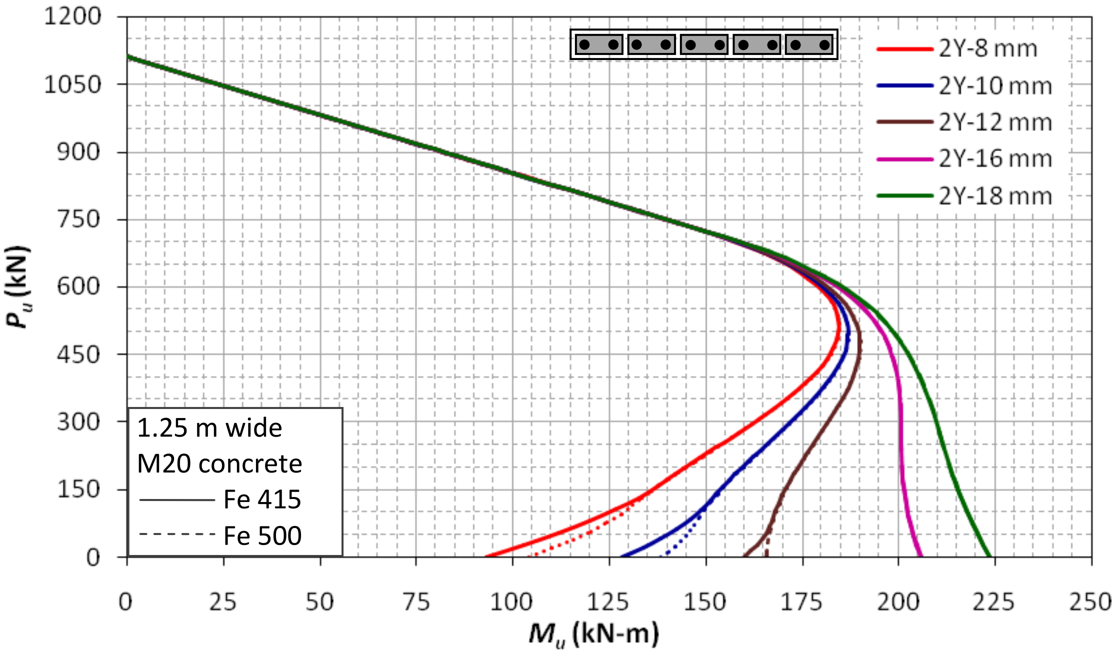


(a) using M20 concrete

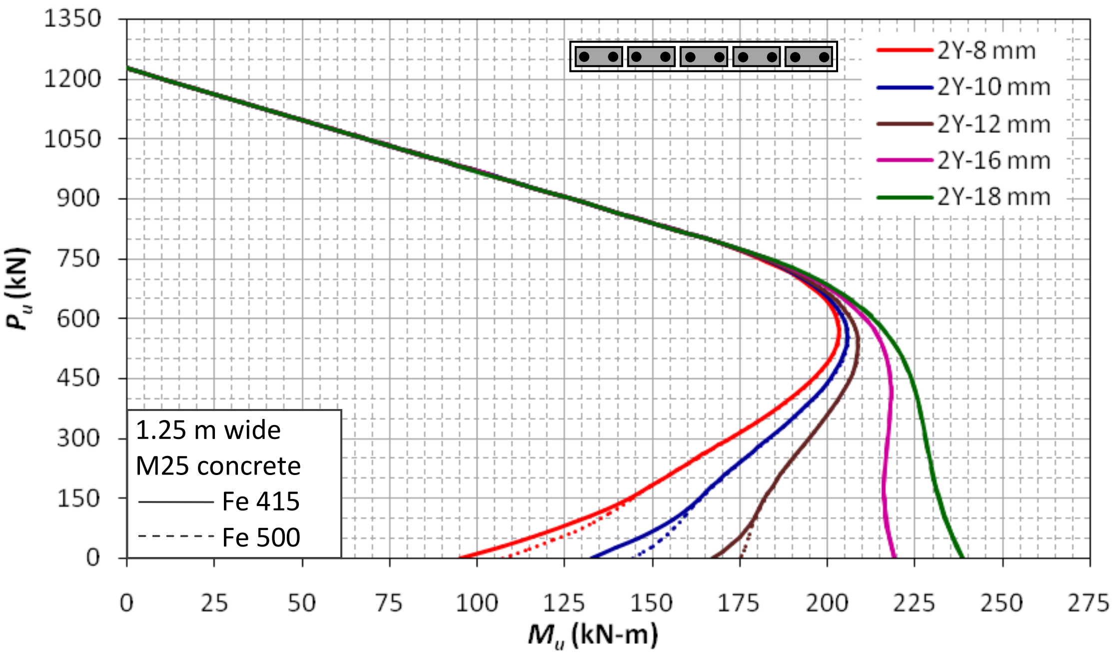


(b) using M25 concrete

Fig. 11 Design P_u-M_u plots for **1.0 m wide** GFRG panel with two bars in each cavity

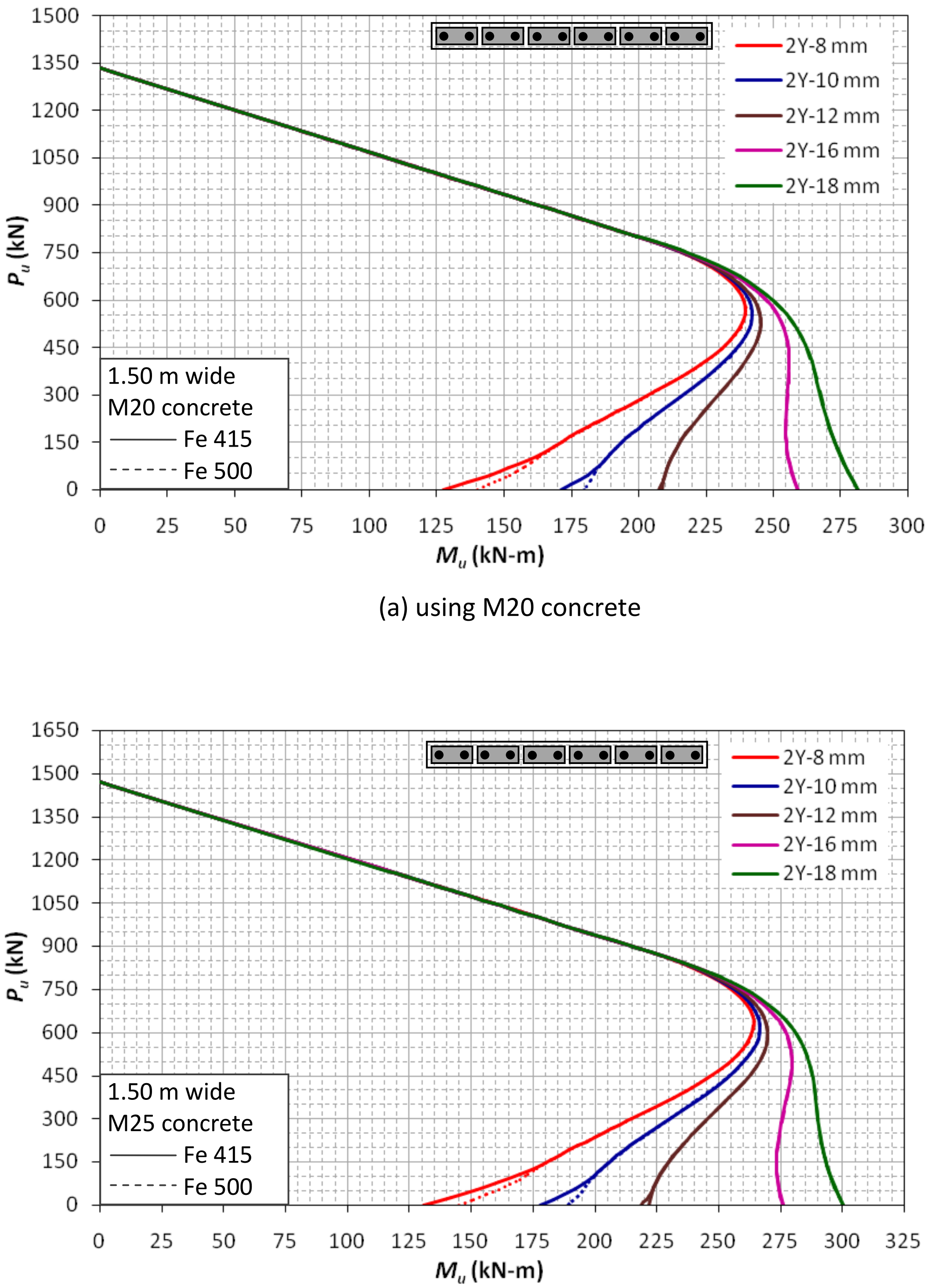


(a) using M20 concrete



(b) using M25 concrete

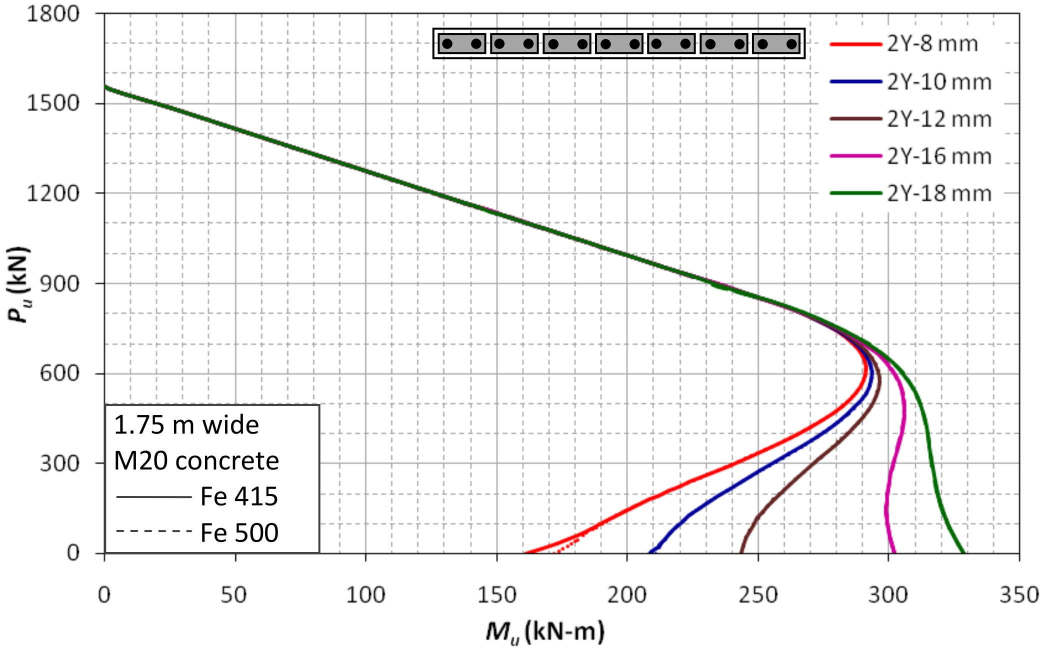
Fig. 12 Design P_u-M_u plots for **1.25 m wide** GFRG panel with two bars in each cavity



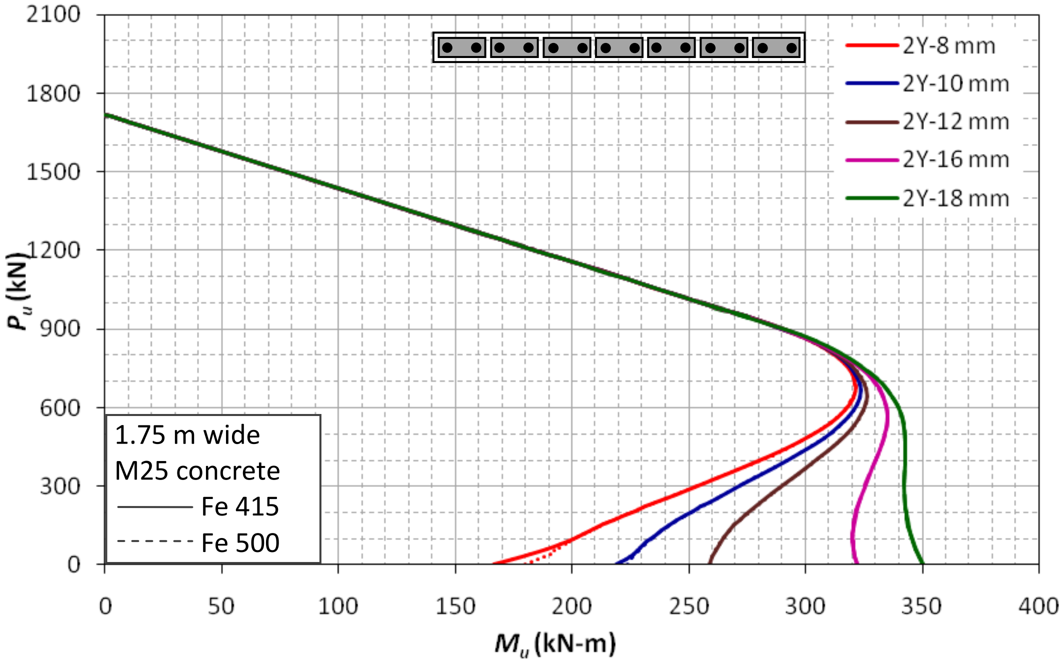
(a) using M20 concrete

(b) using M25 concrete

Fig. 13 Design P_u-M_u plots for **1.50 m wide** GFRG panel with two bars in each cavity

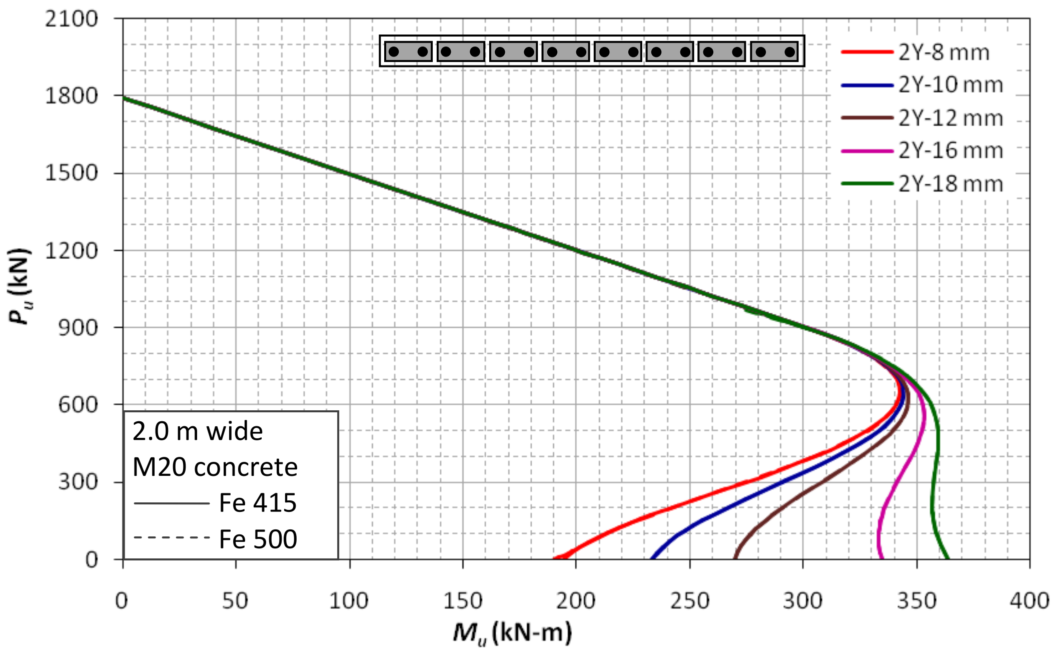


(a) using M20 concrete

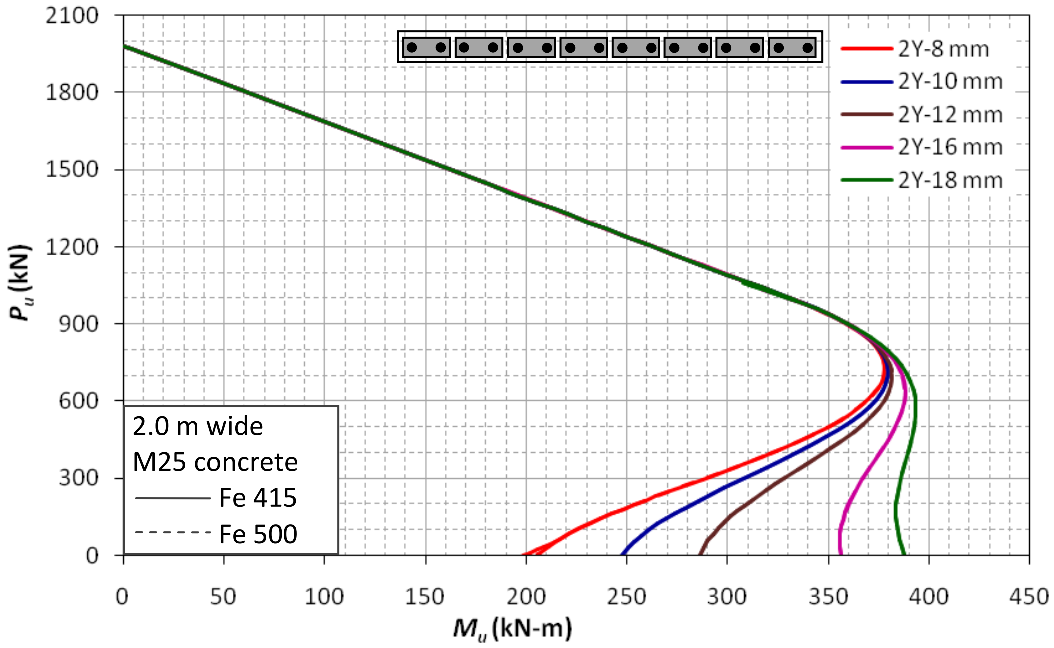


(b) using M25 concrete

Fig. 14 Design P_u-M_u plots for **1.75 m wide** GFRG panel with two bars in each cavity

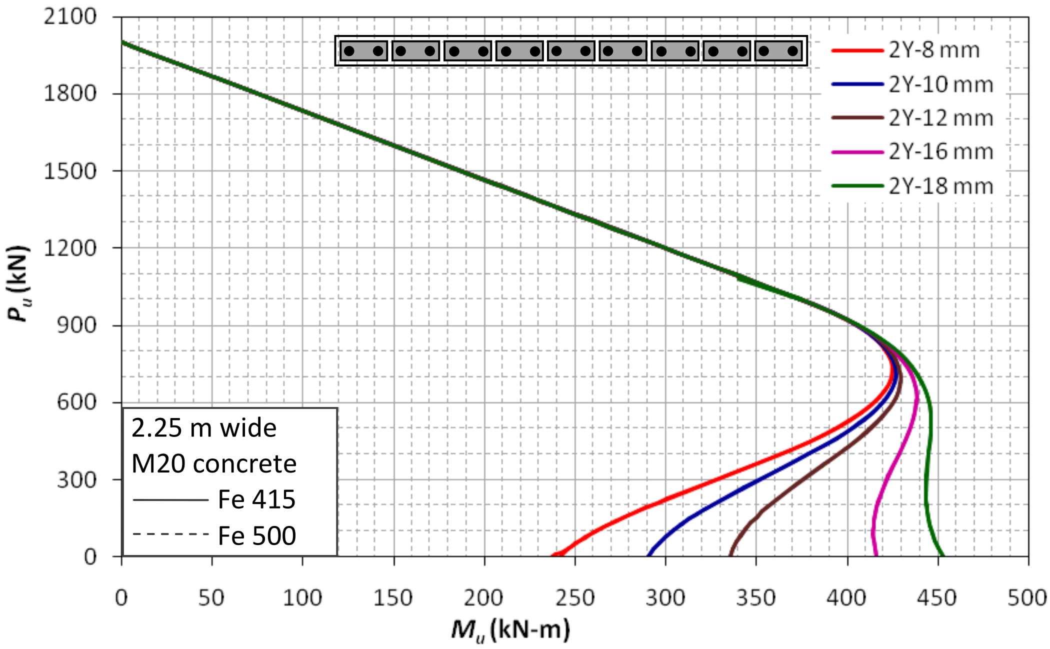


(a) using M20 concrete

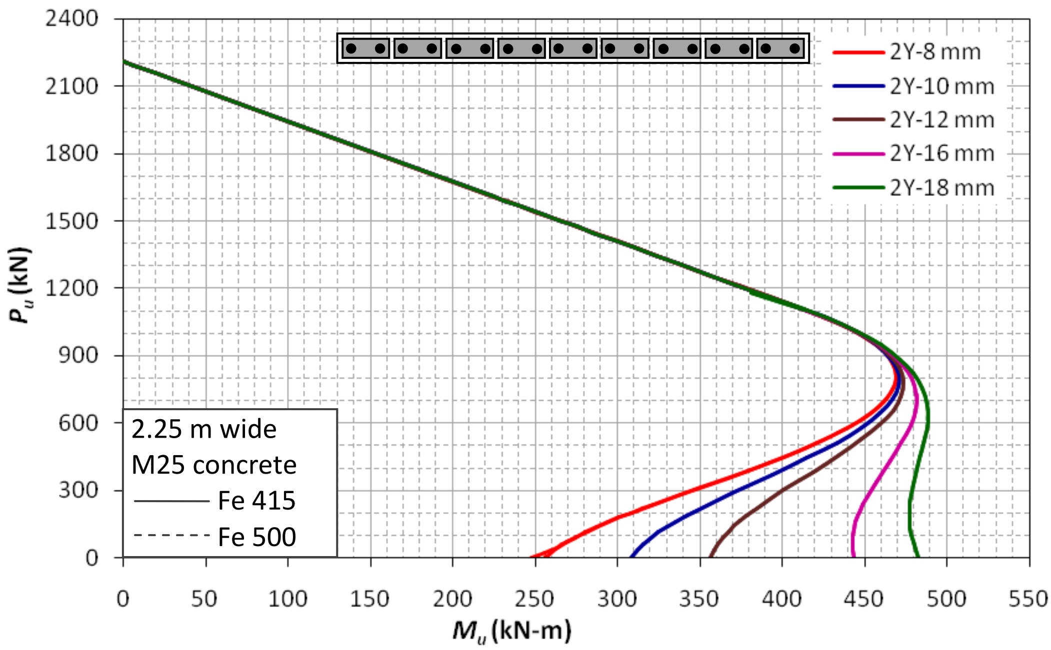


(b) using M25 concrete

Fig. 15 Design P_u-M_u plots for **2.0 m wide** GFRG panel with two bars in each cavity

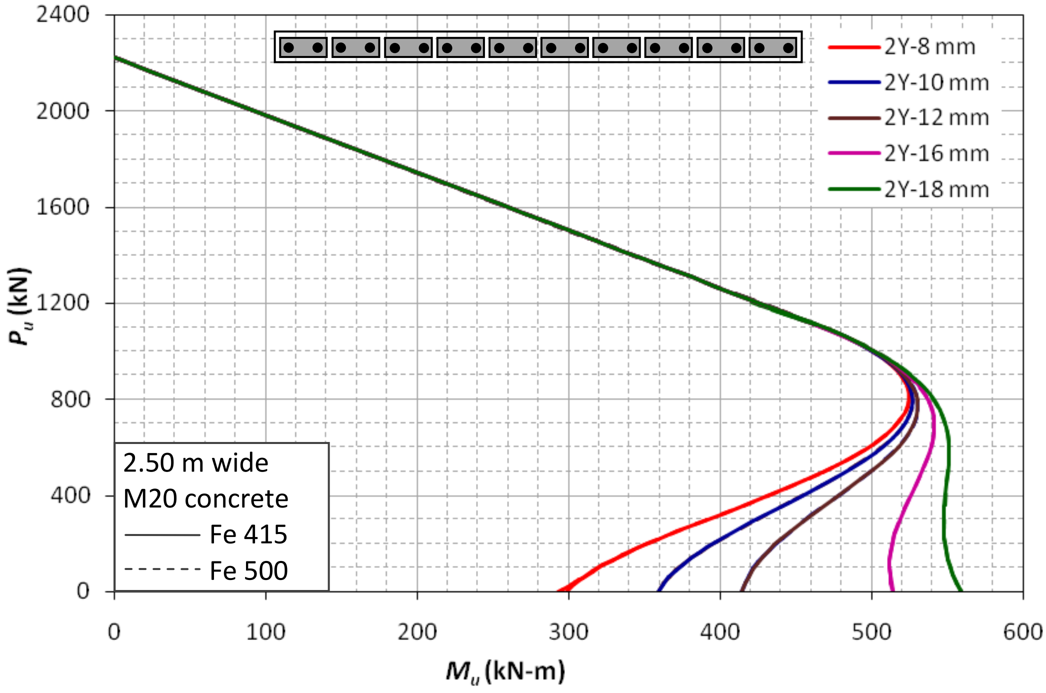


(a) using M20 concrete

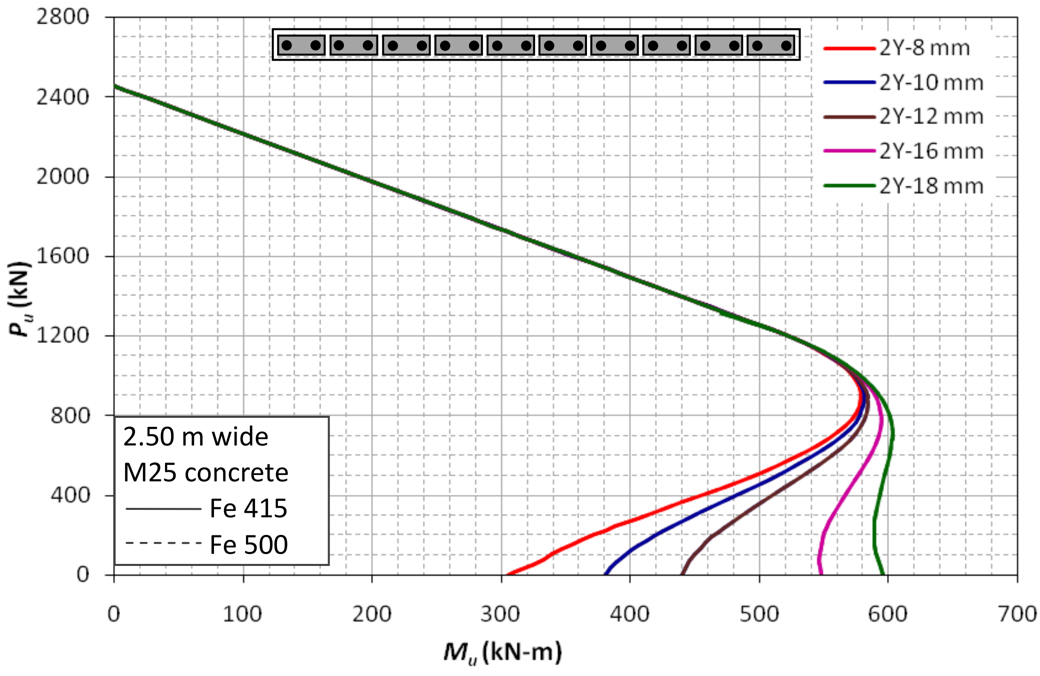


(b) using M25 concrete

Fig. 16 Design P_u-M_u plots for **2.25 m wide** GFRG panel with two bars in each cavity

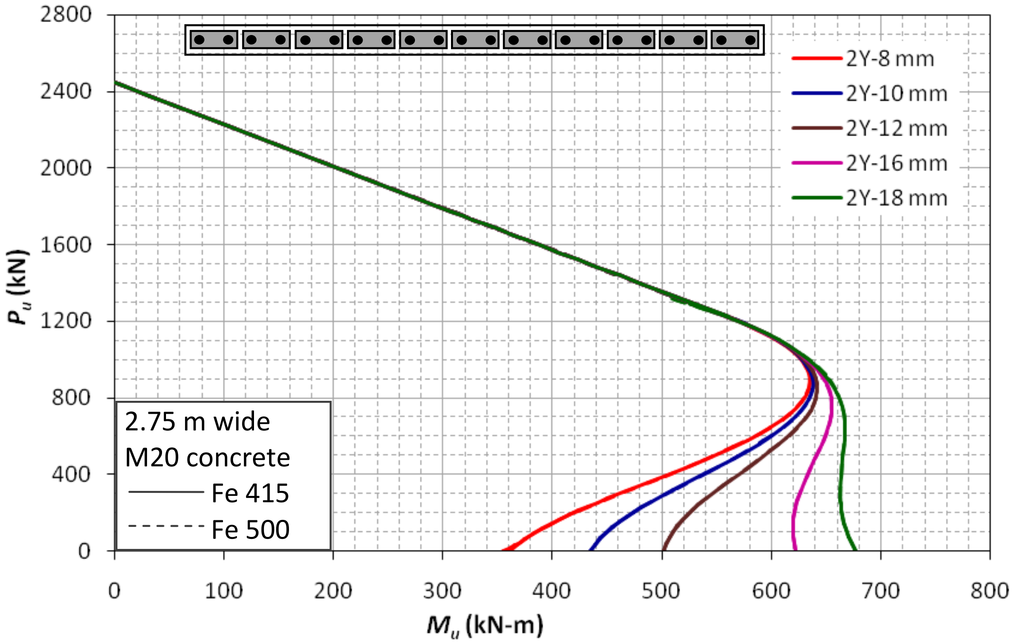


(a) using M20 concrete

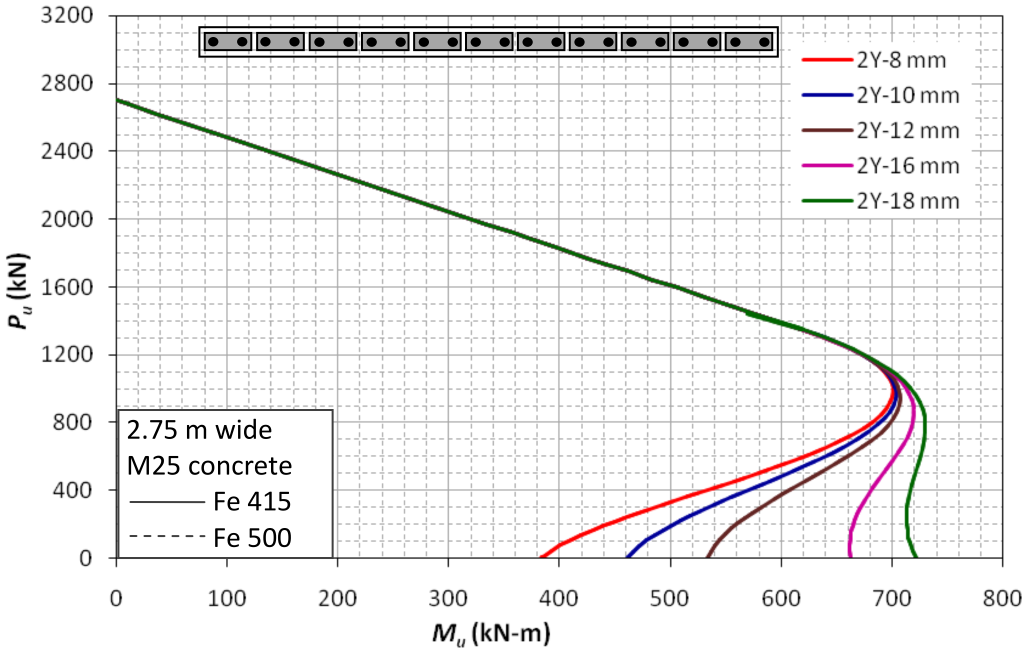


(b) using M25 concrete

Fig. 17 Design P_u-M_u plots for **2.50 m wide** GFRG panel with two bars in each cavity

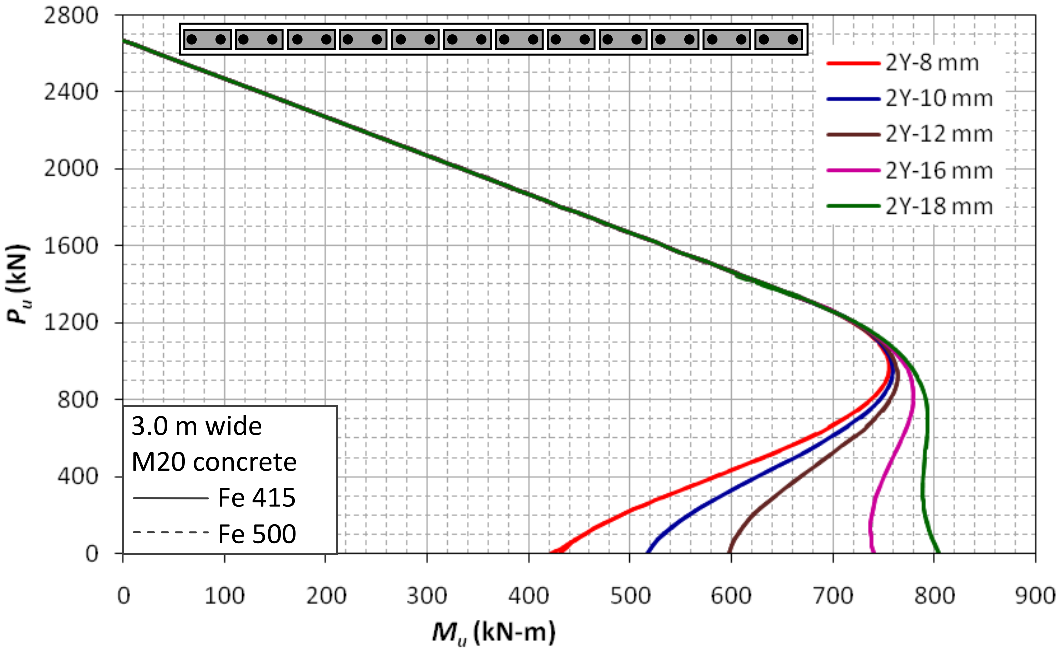


(a) using M20 concrete

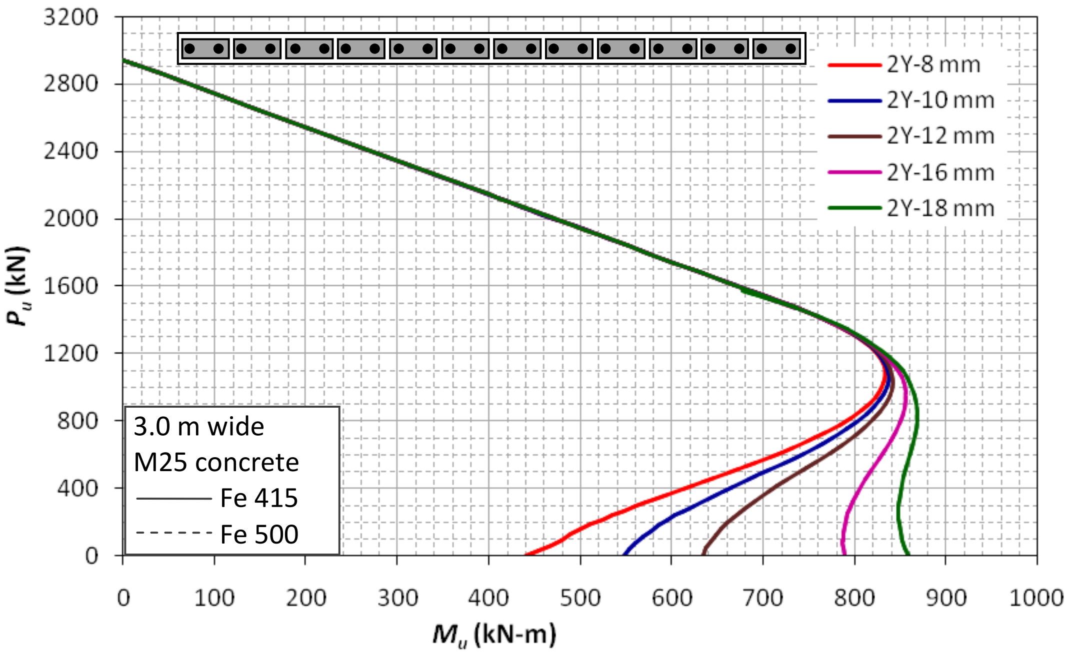


(b) using M25 concrete

Fig. 18 Design P_u-M_u plots for **2.75 m wide** GFRG panel with two bars in each cavity

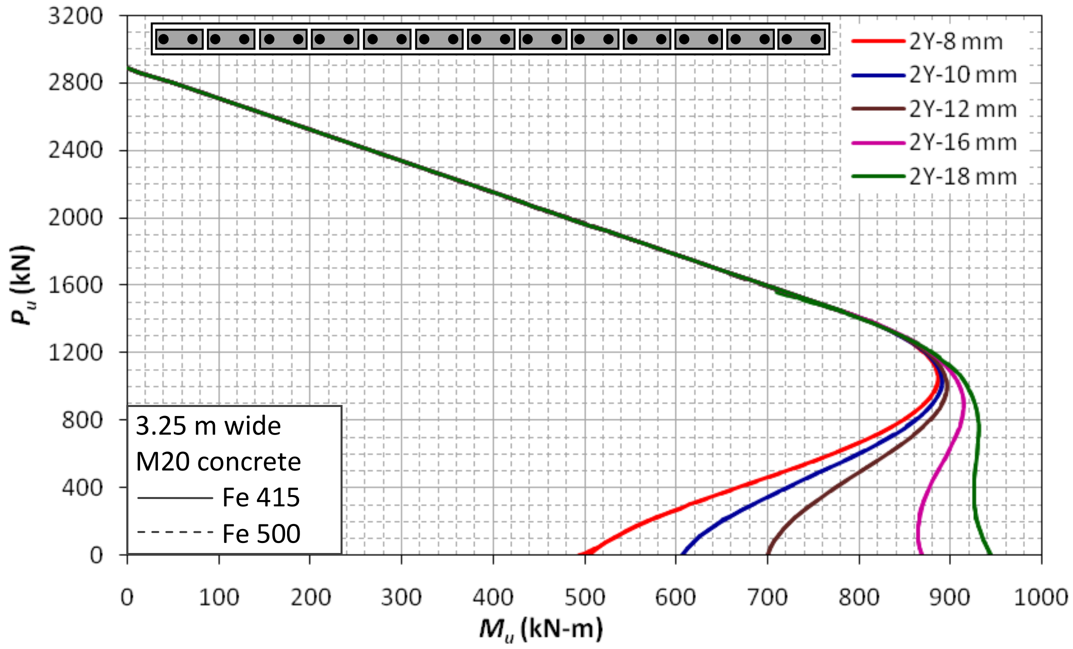


(a) using M20 concrete

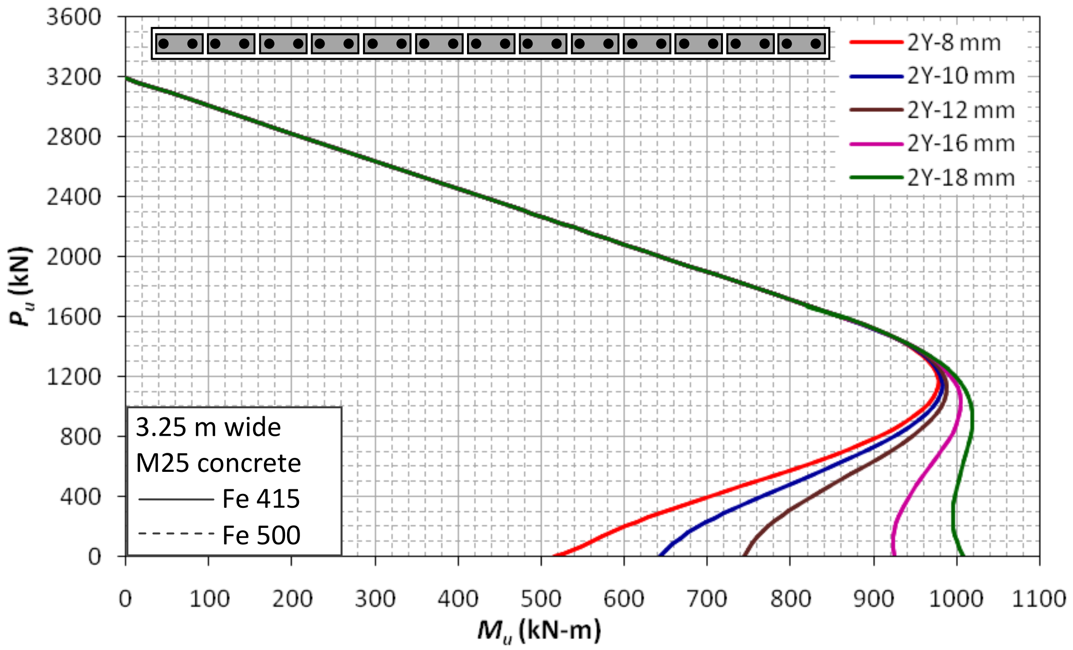


(b) using M25 concrete

Fig. 19 Design P_u-M_u plots for **3.0 m wide** GFRG panel with two bars in each cavity

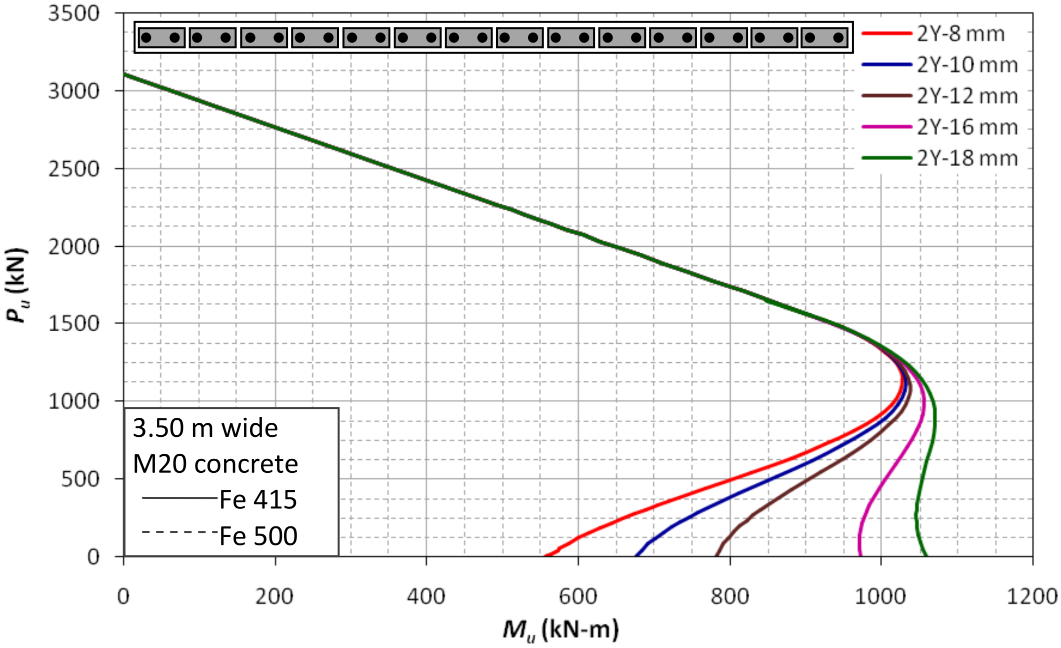


(a) using M20 concrete

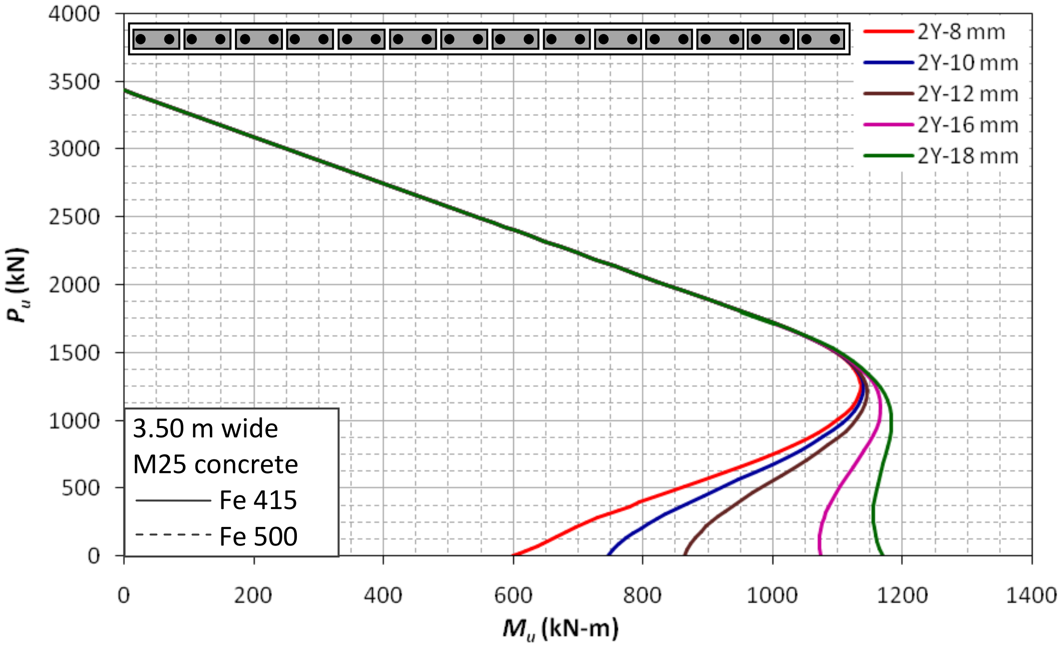


(b) using M25 concrete

Fig. 20 Design P_u-M_u plots for **3.25 m wide** GFRG panel with two bars in each cavity



(a) using M20 concrete



(b) using M25 concrete

Fig. 21 Design P_u-M_u plots for **3.50 m wide** GFRG panel with two bars in each cavity

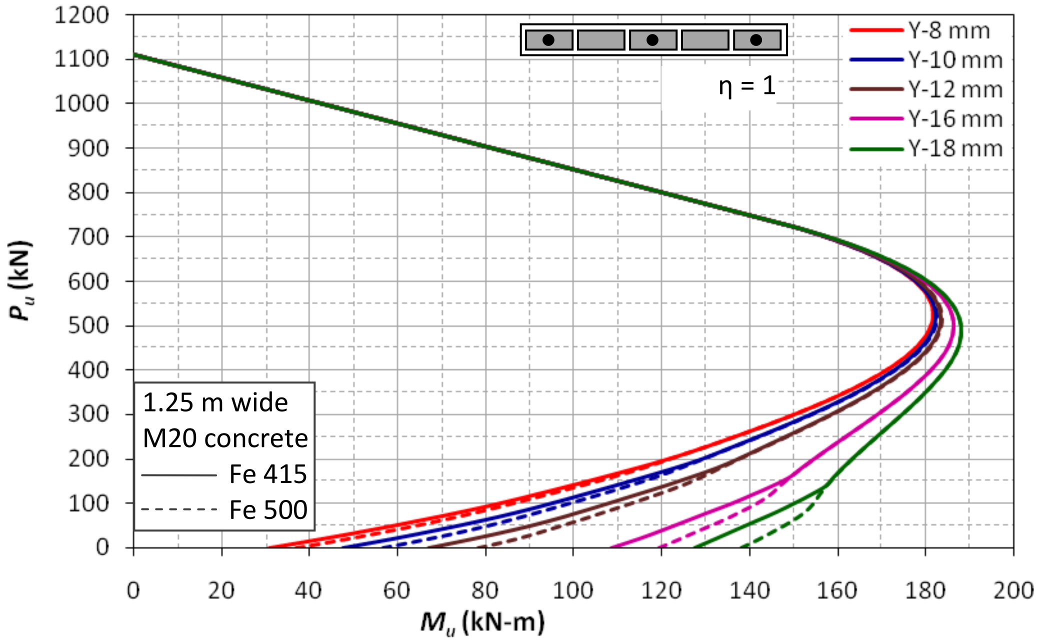


Fig. 22 Design P_u-M_u plots for **1.25 m wide** GFRG panel with all cavities infilled with M20 concrete and alternative cavities reinforced with single bar

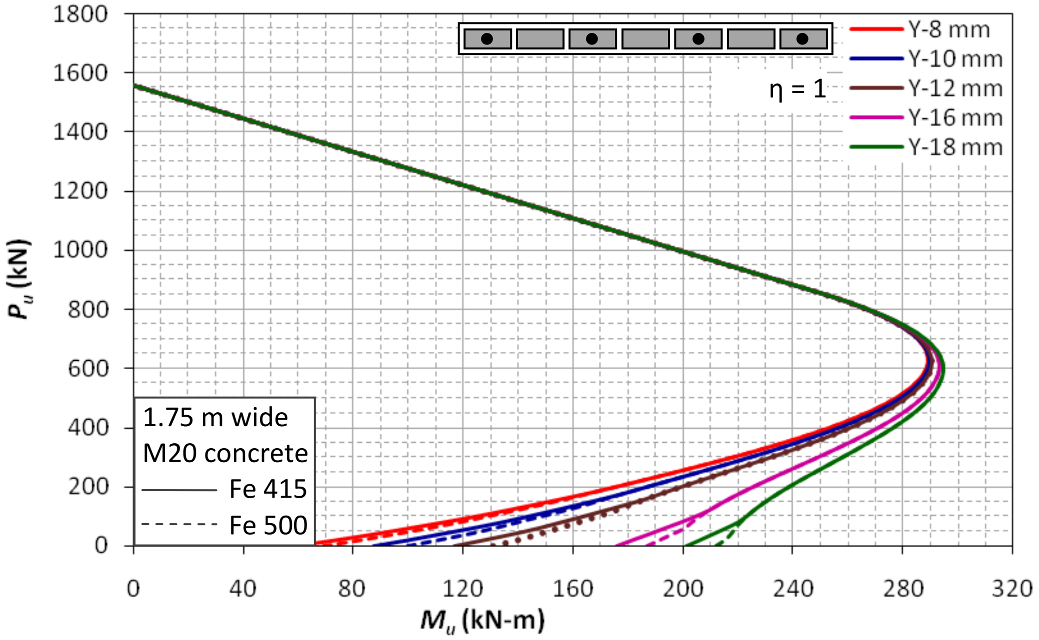


Fig. 23 Design P_u-M_u plots for **1.75 m wide** GFRG panel with all cavities infilled with M20 concrete and alternative cavities reinforced with single bar

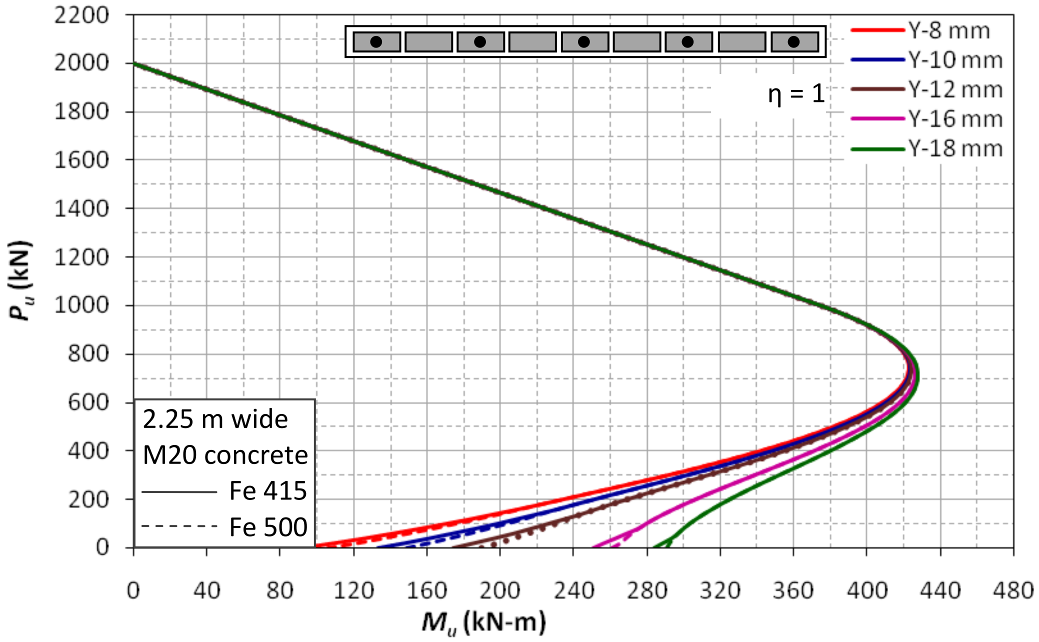


Fig. 24 Design P_u-M_u plots for **2.25 m wide** GFRG panel with all cavities infilled with M20 concrete and alternative cavities reinforced with single bar

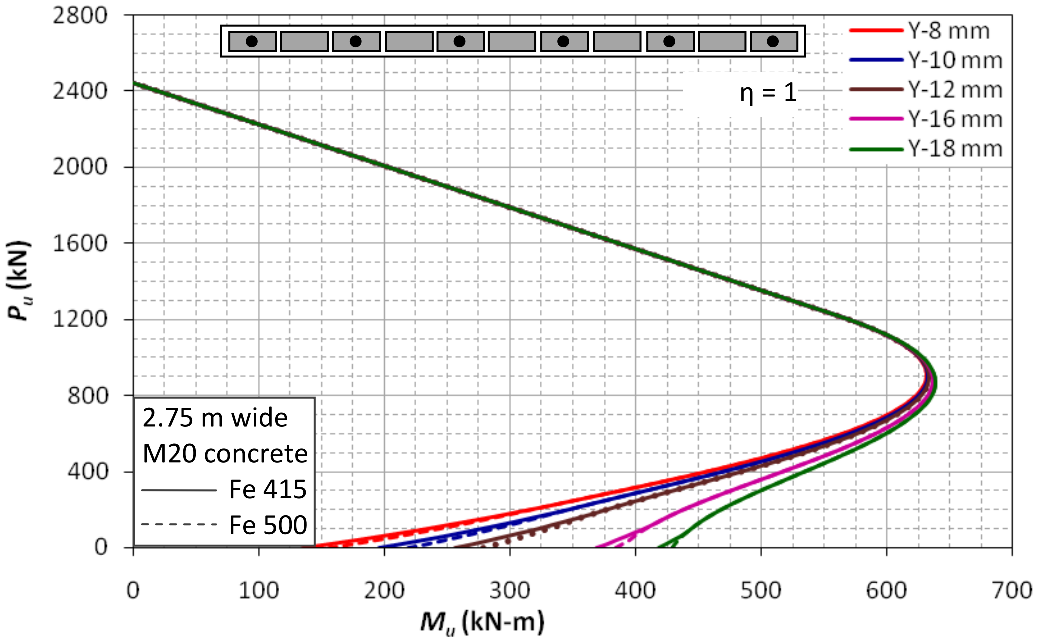


Fig. 25 Design P_u-M_u plots for **2.75 m wide** GFRG panel with all cavities infilled with M20 concrete and alternative cavities reinforced with single bar

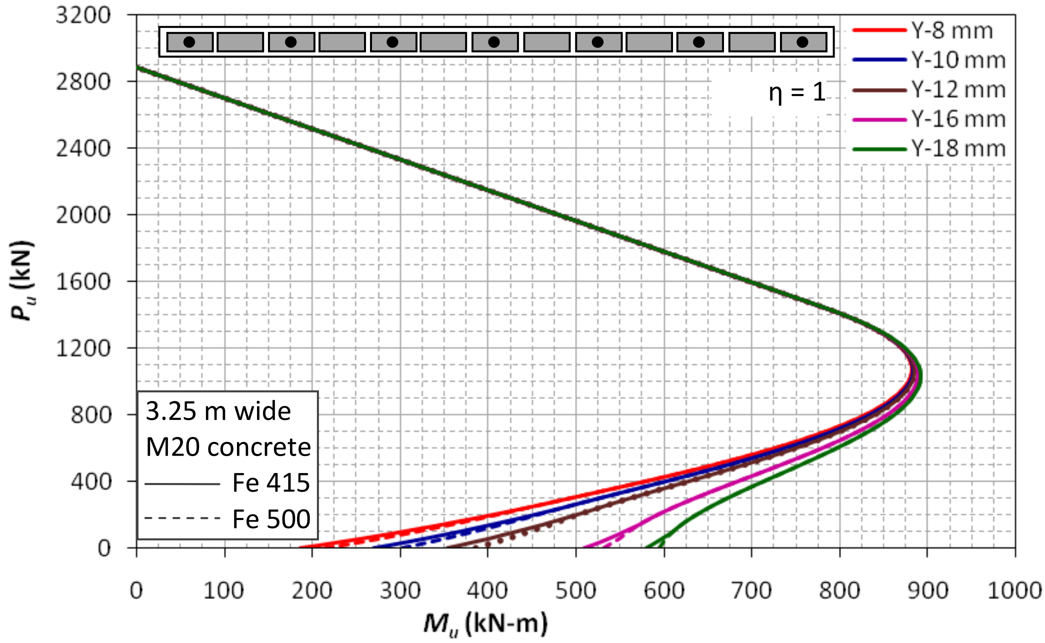


Fig. 26 Design P_u-M_u plots for **3.25 m wide** GFRG panel with all cavities infilled with M20 concrete and alternative cavities reinforced with single bar

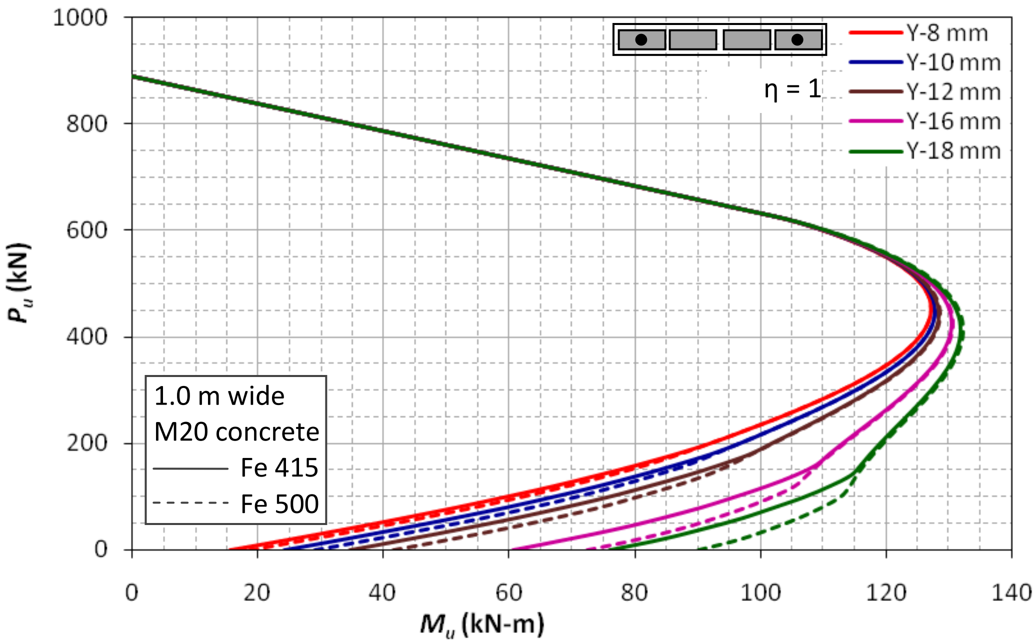


Fig. 27 Design P_u-M_u plots for **1.0 m wide** GFRG panel with all cavities infilled with M20 concrete and end cavities reinforced with single bar

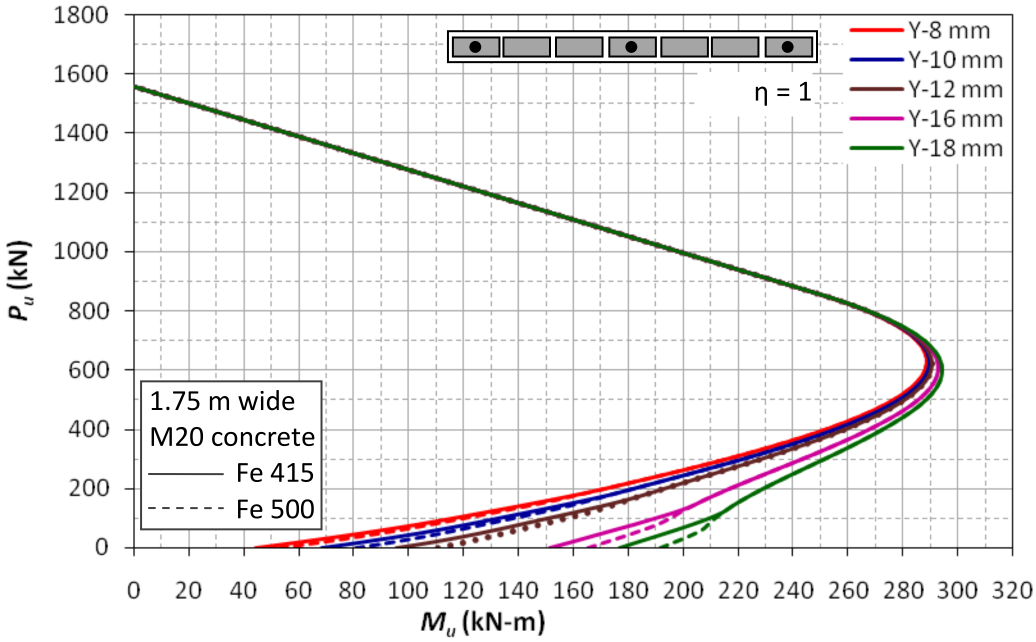


Fig. 28 Design P_u-M_u plots for **1.75 m wide** GFRG panel with all cavities infilled with M20 concrete and every third cavity reinforced with single bar

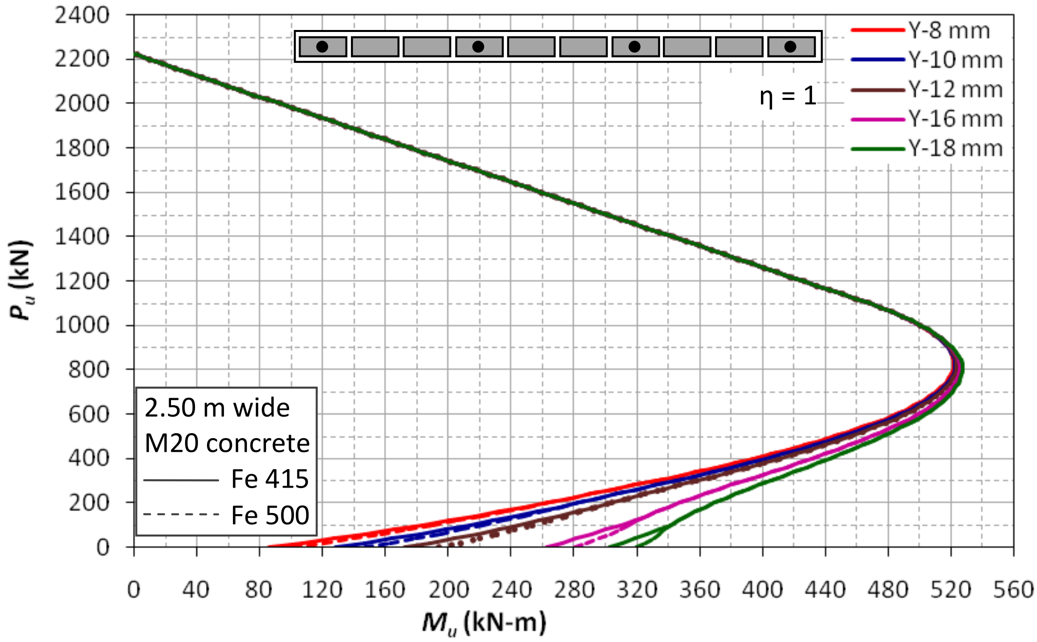


Fig. 29 Design P_u-M_u plots for **2.50 m wide** GFRG panel with all cavities infilled with M20 concrete and every third cavity reinforced with single bar

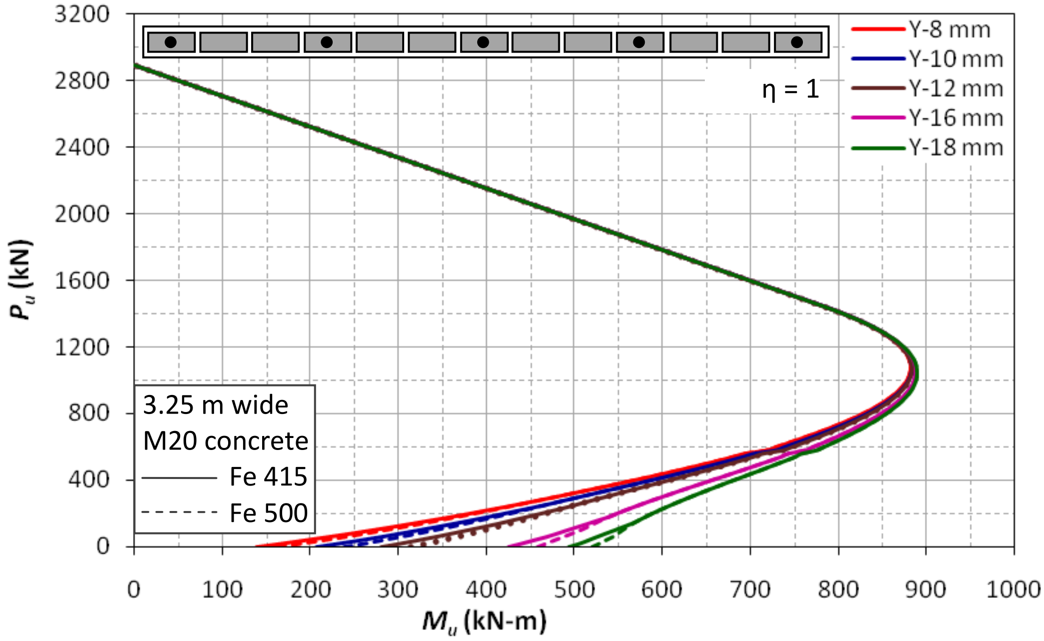


Fig. 30 Design P_u-M_u plots for **3.25 m wide** GFRG panel with all cavities infilled with M20 concrete and every third cavity reinforced with single bar

ANNEX C

(Clause 4.6)

STRUCTURAL DETAILING OF GFRG BUILDINGS

C-1 Connection between GFRG Walls and Foundation

C-1.1 All GFRG wall panels at the ground floor are to be erected over a network of RC plinth beams supported on suitable foundation (typically, strip masonry footings). 'Starter bars' shall be embedded in the RC plinth beams, at precise locations where the cavities are to be filled with reinforced concrete, with appropriate lap length (refer Fig. 31). In the case of multi-storeyed buildings, where the base shear due to lateral loading (wind or earthquake) is required to be transferred to the foundation, appropriate detailing such as provision of shear keys at the starter bar locations, shall be provided.

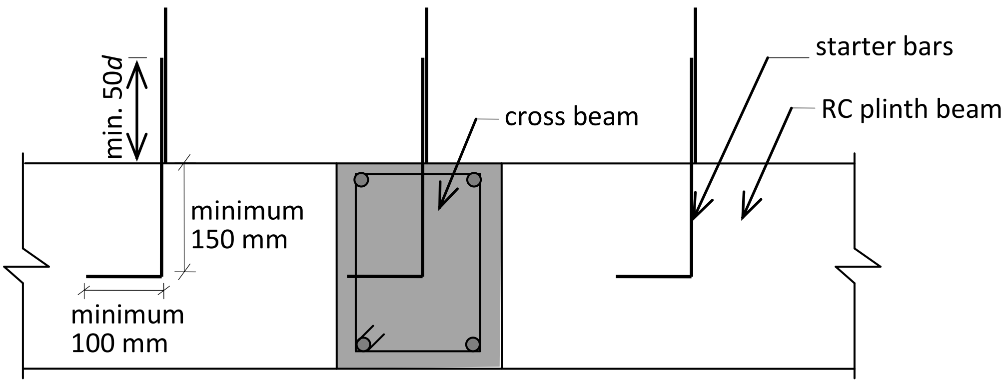


Fig. 31 Provision of starter bars in RC plinth beams for the erection of GFRG panels

C-1.2 For constructing an additional GFRG floor above an existing RC building, connectivity between GFRG wall and the existing floor can be achieved by proper detailing (insertion of starter bars with proper anchorage) as shown in Fig. 32. If the existing roof slab does not have sufficient depth for anchorage, an additional RC beam may be constructed above the roof before erecting the GFRG walls.

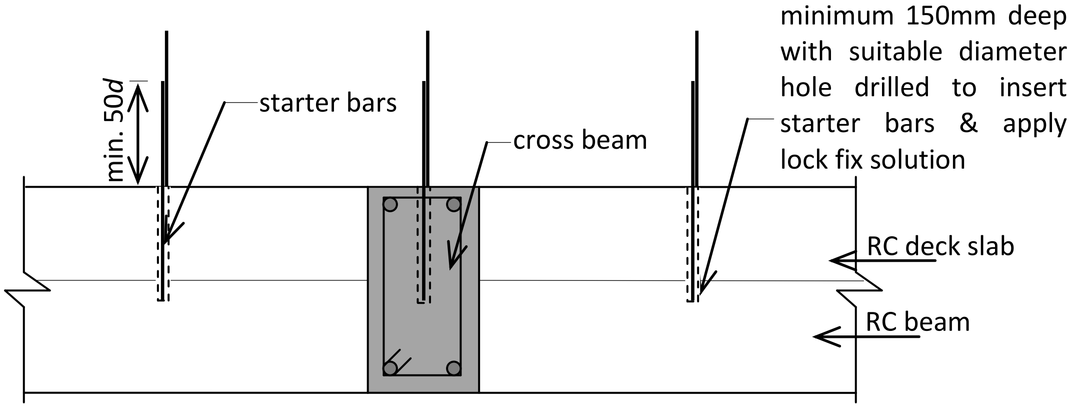


Fig. 32 Starter bars in case of an existing RC floor/roof slab

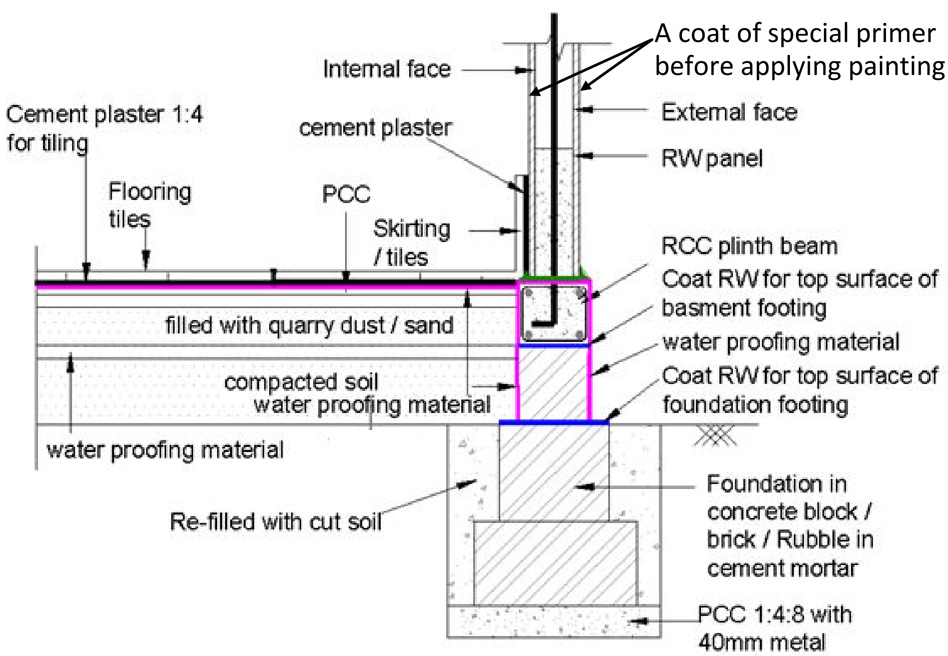


Fig.33 Foundation, basement, plinth beam and start-up bars for erection of GFRG panels

C-1.3 In the connection between the cross walls, adjacent faces of the walls have to be cut open and the adjoining cavities shall be infilled with reinforced concrete to have a monolithic connection between them, as shown in Fig. 34.

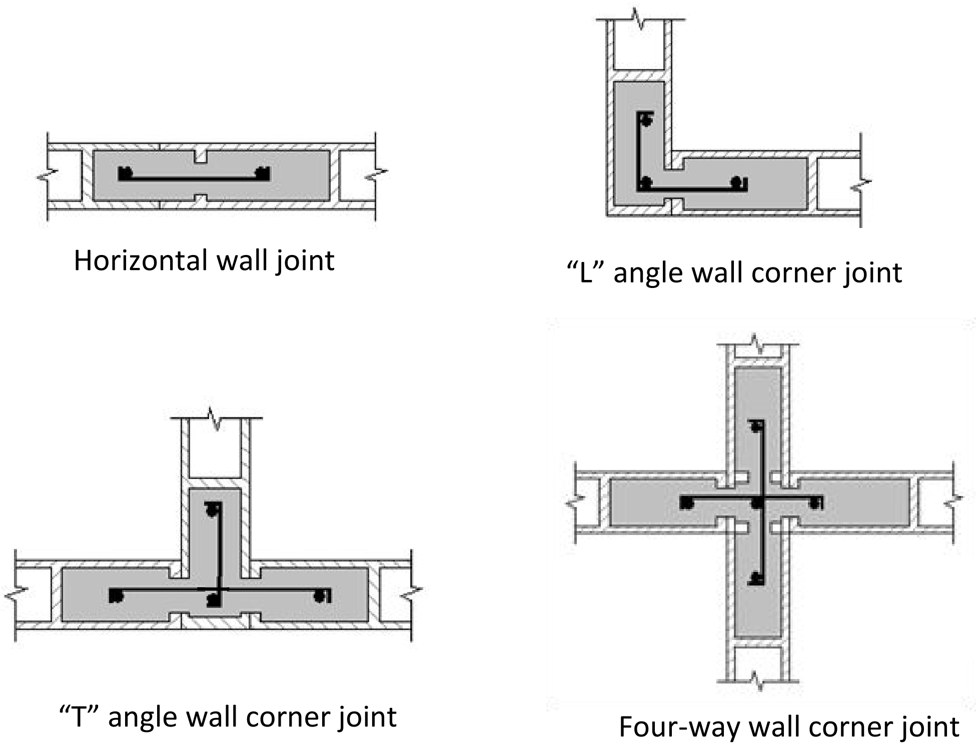


Fig.34 Typical wall corner joints

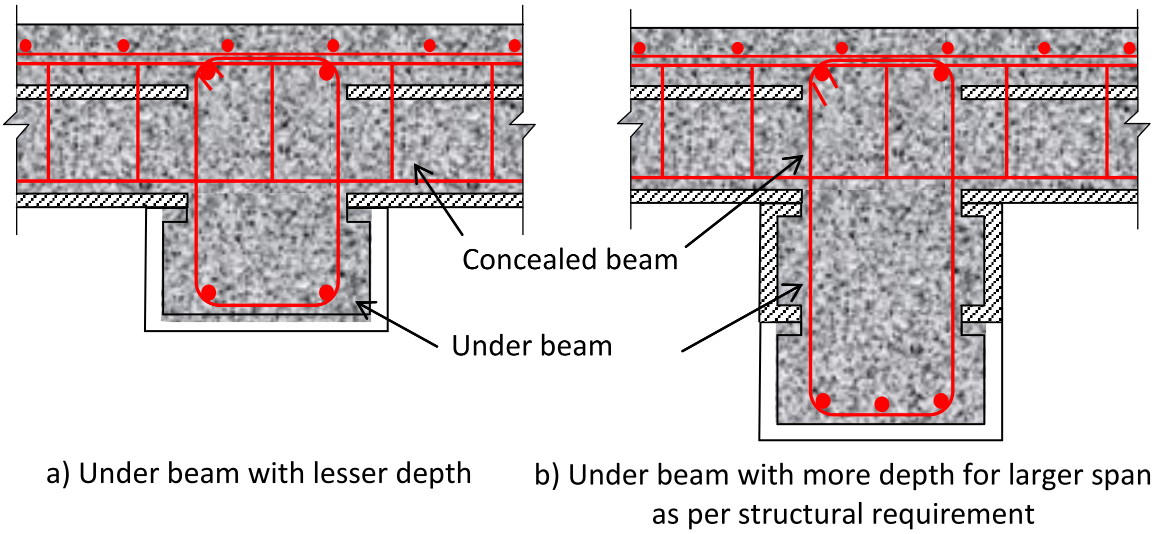


Fig.35 GFRG-RC composite embedded beam for long span floors

C-2 For external doors and windows with RC sunshade, it is mandatory to provide embedded RC lintel cum sunshade with a minimum of 250mm bearing on either sides with suitable reinforcement including stirrups, and adequate anchorage for proper connectivity between lintel, sunshade and vertical wall (refer Figs.36&37).

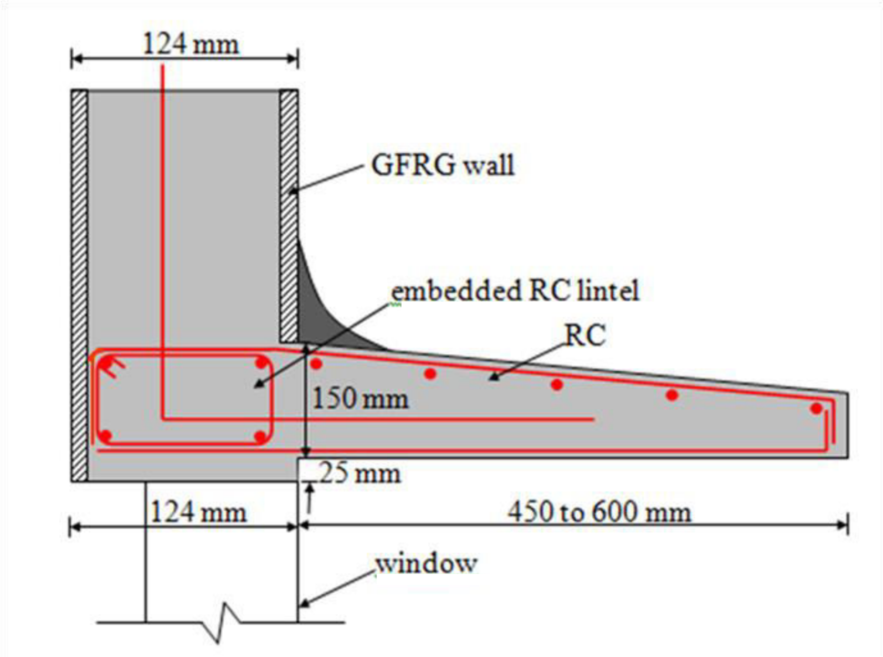


Fig.36 Connectivity between lintel, sunshade and GFRG panel

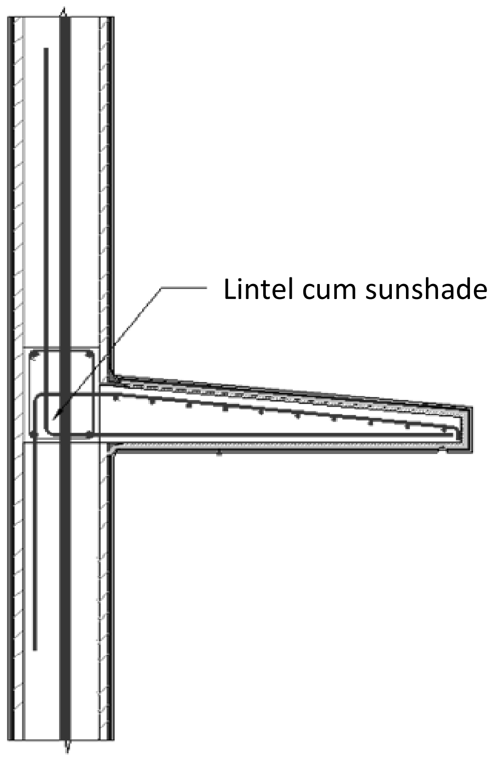


Fig.37 Lintel, sunshade and GFRG wall

C-3 Proper connectivity should be provided when using GFRG panel as waist slab of stair case, provided with both mid landing and floor landing under beams as per the structural design (referFigs.38 and39).

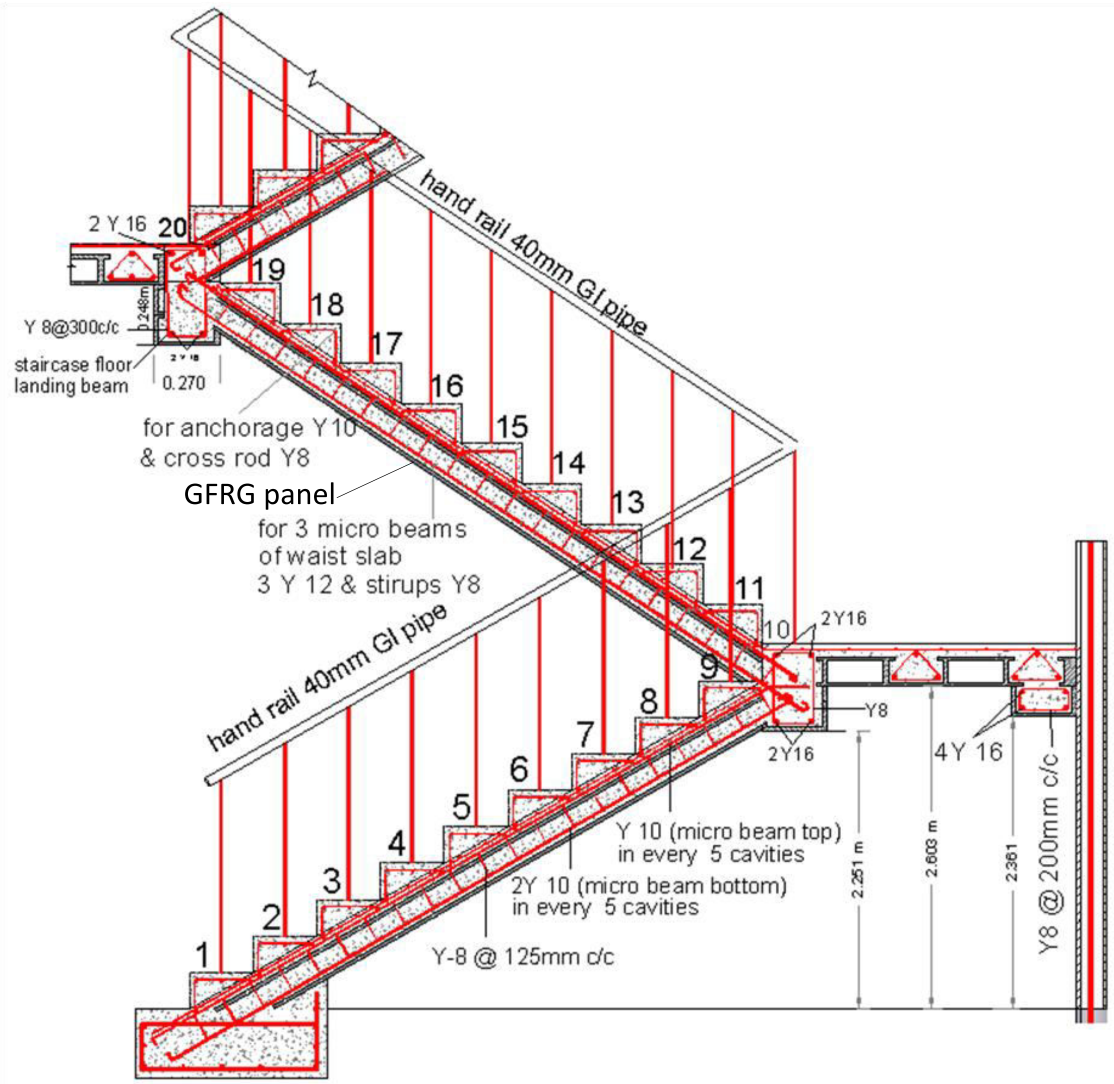


Fig.38(a) Cross-section of staircase

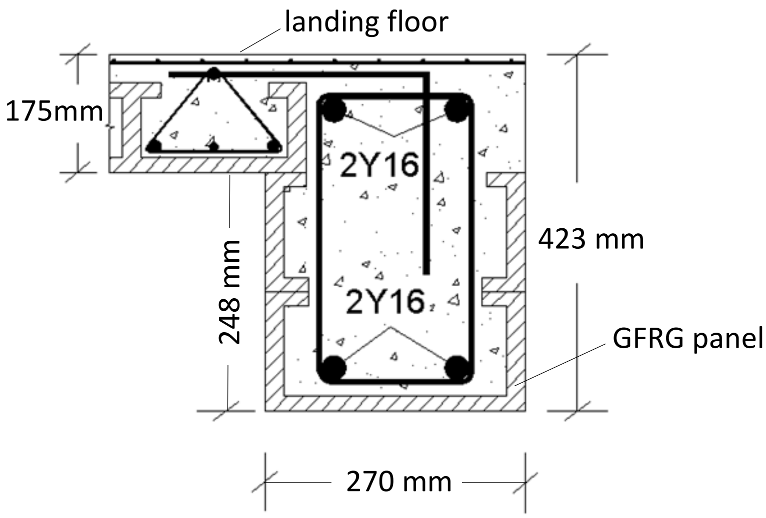


Fig.38(b) Staircase floor landing beam

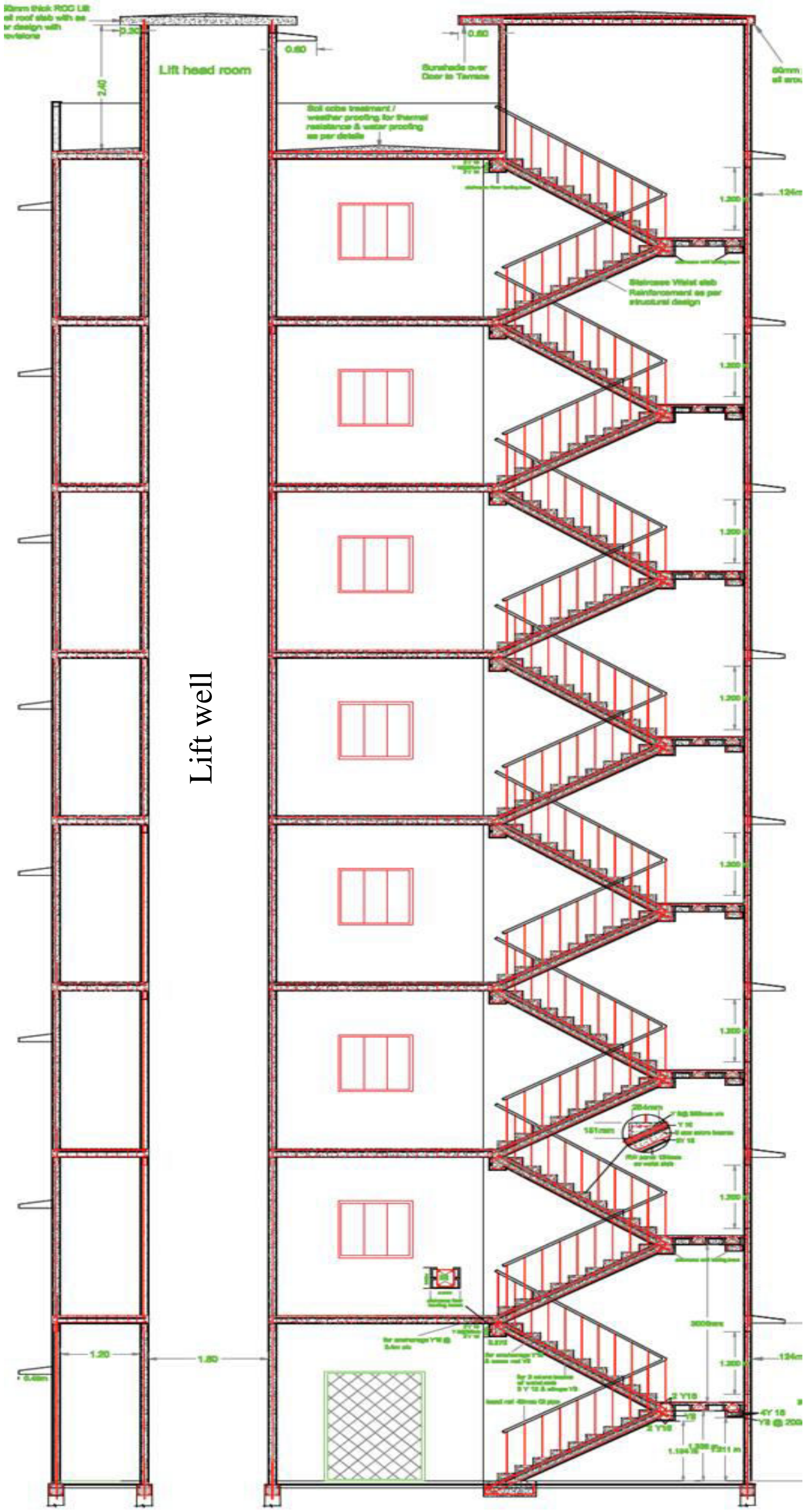


Fig. 39 Cross-section of GFRG lift well

C-4 Proper connectivity for sunken floor slab, shall be provided between the floor slab and vertical walls for bath/toilets, for providing sanitary and water piping in GFRG buildings, as per the Manual of Waterproofing of GFRG/Rapidwall Structures (2014) (refer Fig. 40).

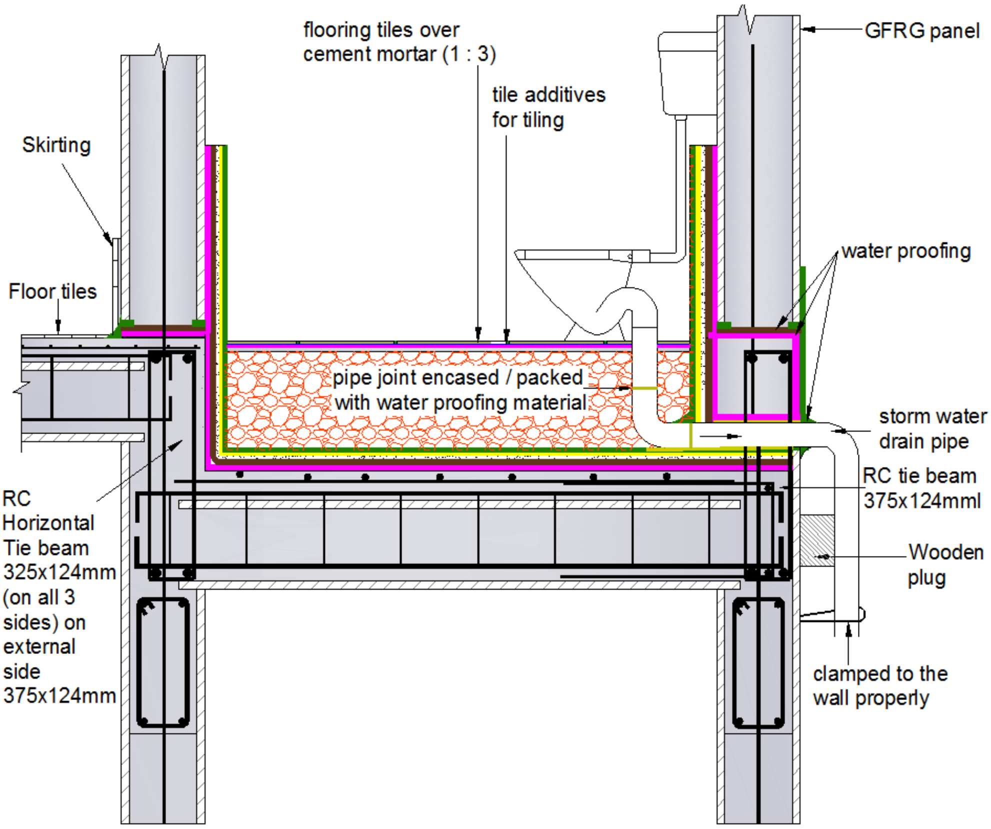


Fig.40 Cross-section of sunken floor (to be used in bath/toilet/wet area)

C-5 A Minimum clear cover of 25 mm shall be provided for the vertical rebars, whenever two rebars are to be provided in the cavities of the panel, as per the structural design (refer Fig.41).

C-6 Not more than one cavity be left unfilled in a wall (whether external or internal), for electrical cabling or other piping works. It is mandatory to seal off such embedded water pipes or rain water drainage/sanitary piping joints inside the GFRG panel cavity before infill or pour of concrete, using water resistant sealant..

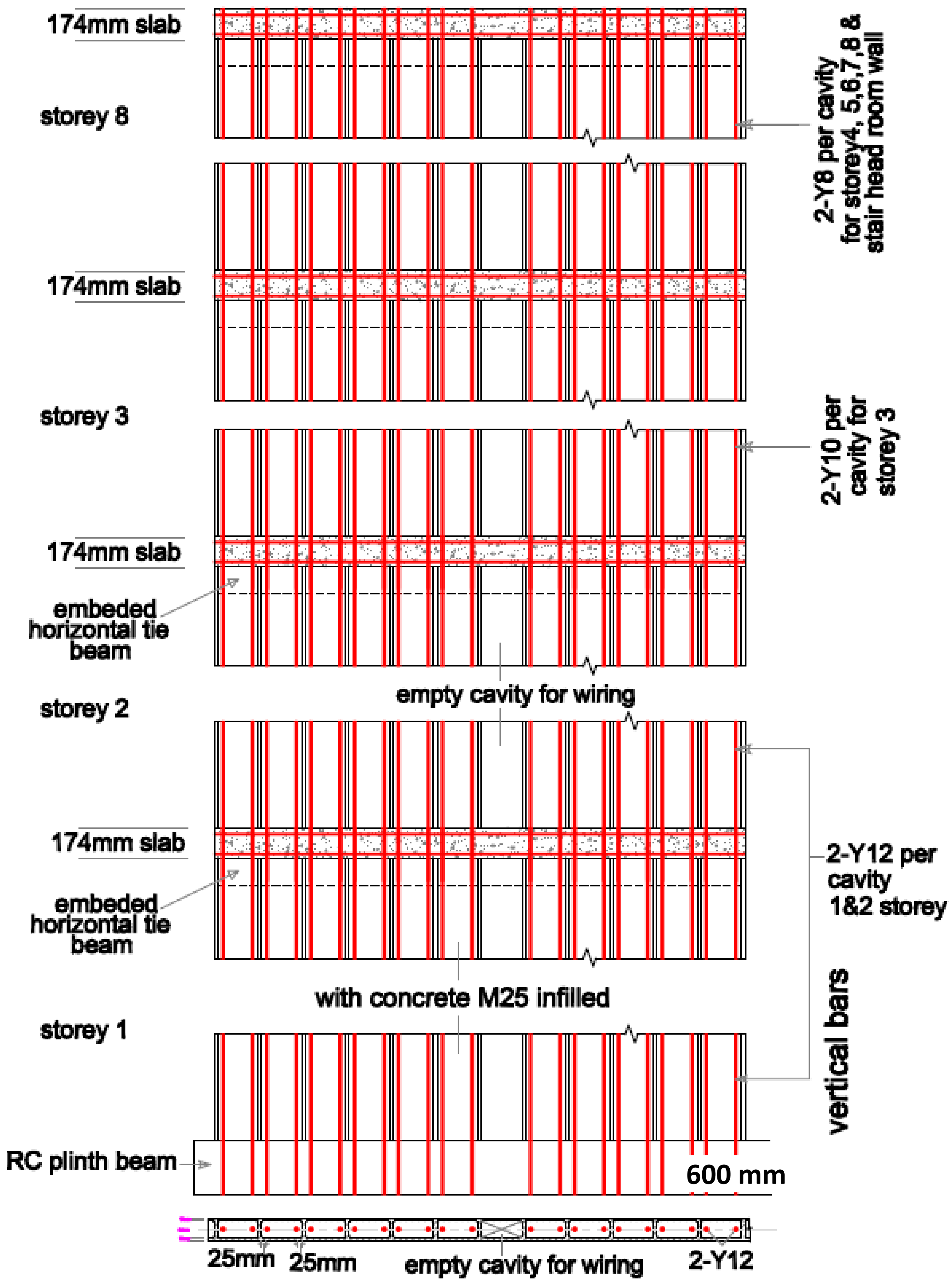


Fig.41 Longitudinal sectional view of walls showing vertical reinforcement details

C-7 Suitable primer (WD P30 & WD Thinner @ 1:1 mix) shall be provided for GFRG wall panels, before painting or providing any thin layer of rendering for luxurious smooth finish, or to rectify any dent or damage caused by handling of panel during its' erection. This primer will penetrate into the skin of the panel by 0.3mm and will form part of the panel material. This shall be applied either by spraying or by roller method either in the factory, or after the construction of the structure, before painting. If rendering is required to be done, it may be over the primer, using water resistant wall putty for external surface and plaster of paris or gypsum based wall plaster for internal wall surface including the corner joints. If the primer is applied after rendering, it may not penetrate into the panel skin and will become ineffective.

C-8 Structural design of GFRG buildings up to 8storeysmay be carried out as per the provisions given in this code and the GFRG Structural Design Manual published by BMTPC (2012), using GFRG panel in combination with RC as a load bearing structure.

C-9 At the junction of GFRG slab panel with the supporting vertical wall, adequate bearing, not less than 40 mm shall be provided as shown in Figs. 42 and 43.

C-10 Proper connectivity between the embedded horizontal RC tie beam, embedded RC concealed beams in slabs, concrete RC screed and vertical rods in the GFRG wall is mandatory to ensure perfect connection between the floor/roof slab and the walling system (refer Figs. 42and 43).

C-11 In case of interior walls, the connection between the floor slab and wall shall be achieved by providing C-bars (refer Fig. 44).

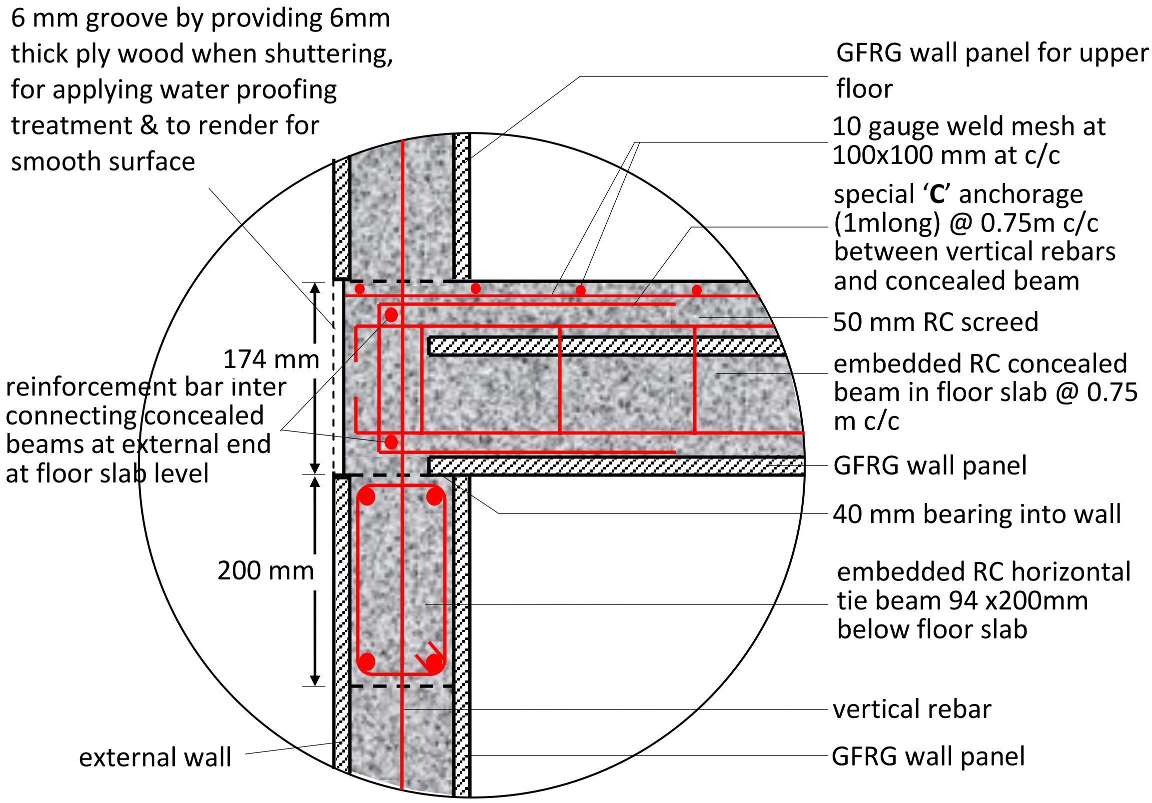


Fig. 42 Connectivity between floor slab and wall-Type 1

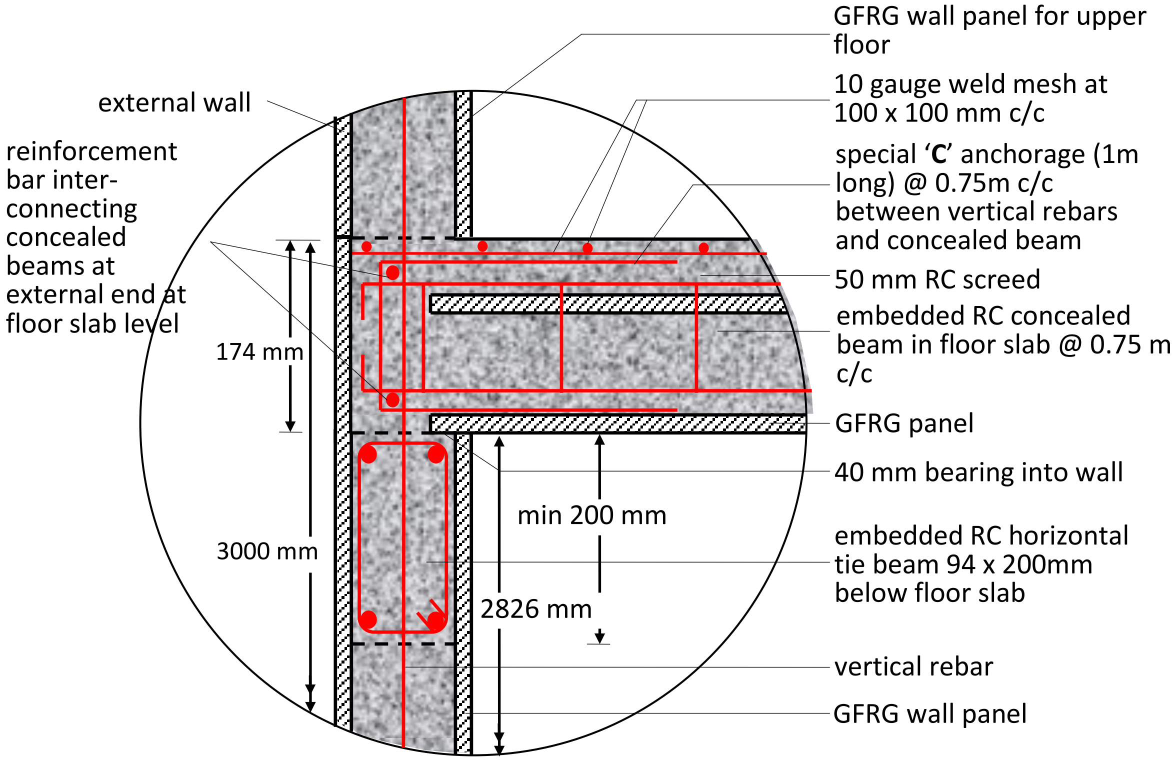


Fig. 43 Connectivity between floor slab and wall-Type 2

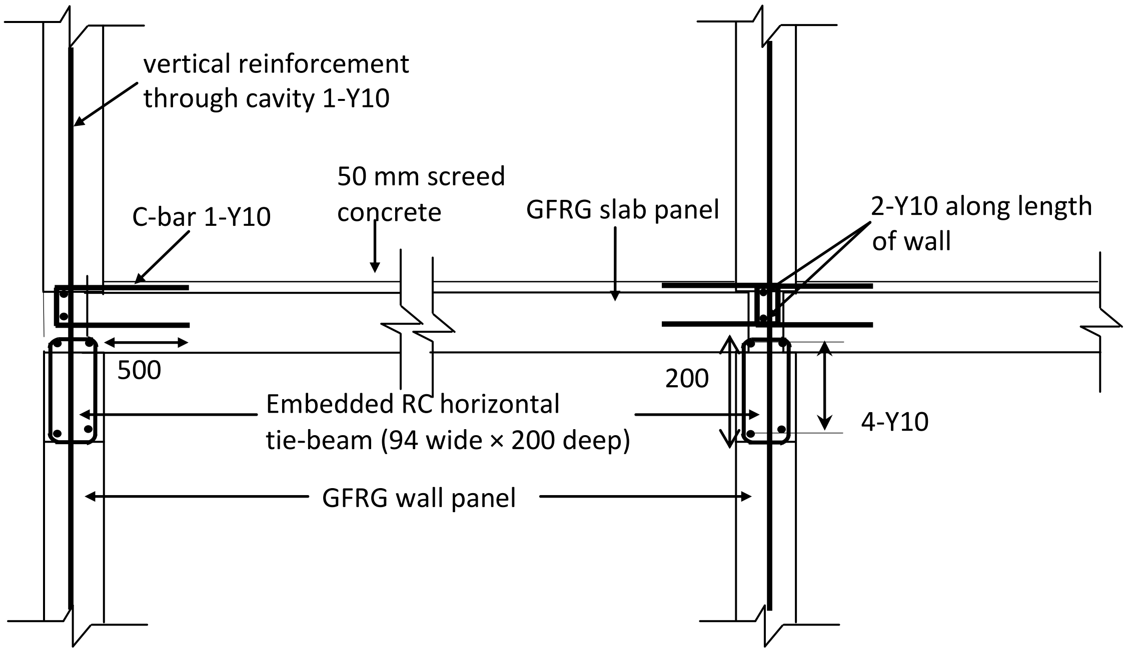


Fig. 44 Reinforcement detailing at the junction of floor slab and wall (All dimensions are in mm)

C-12 In GFRG floor and roof slabs, when the clear span (in the direction of the ribs) exceeds 2.92m, jointing of the GFRG panel shall be treated as shown in Figs 45 to 49.

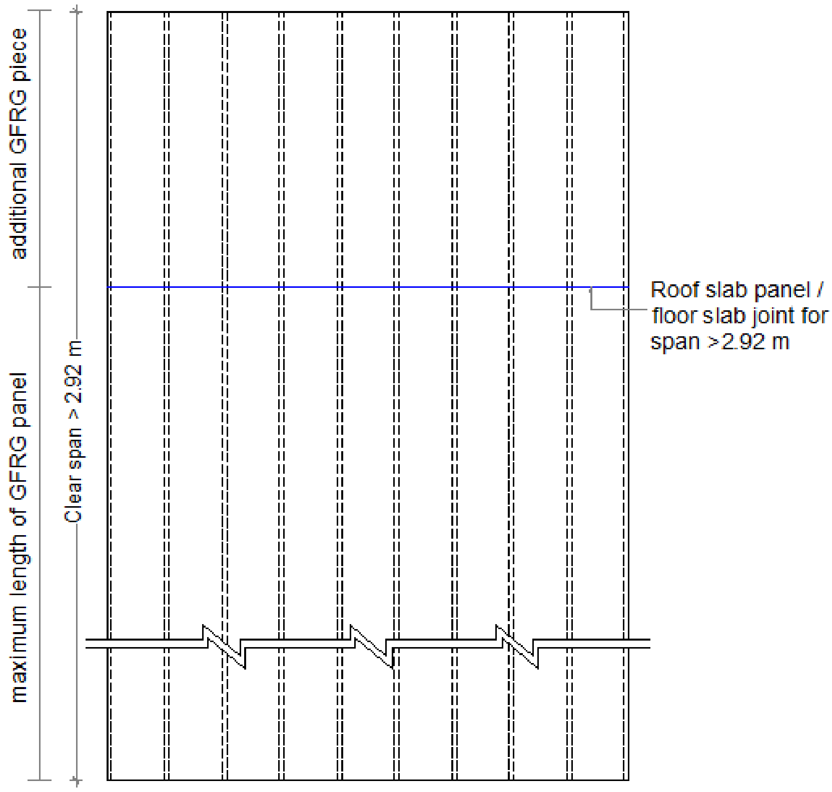


Fig. 45 Joint in GFRG slab panel

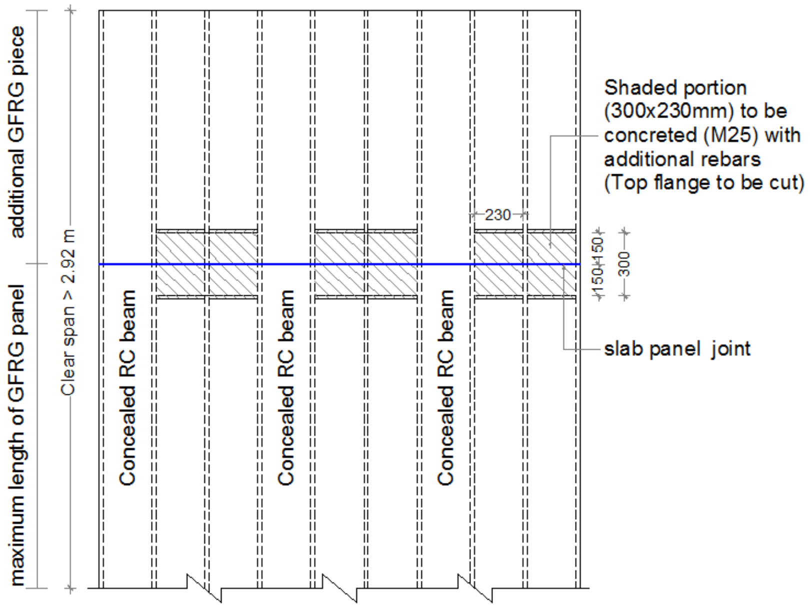


Fig. 46 GFRG slab panel before concreting

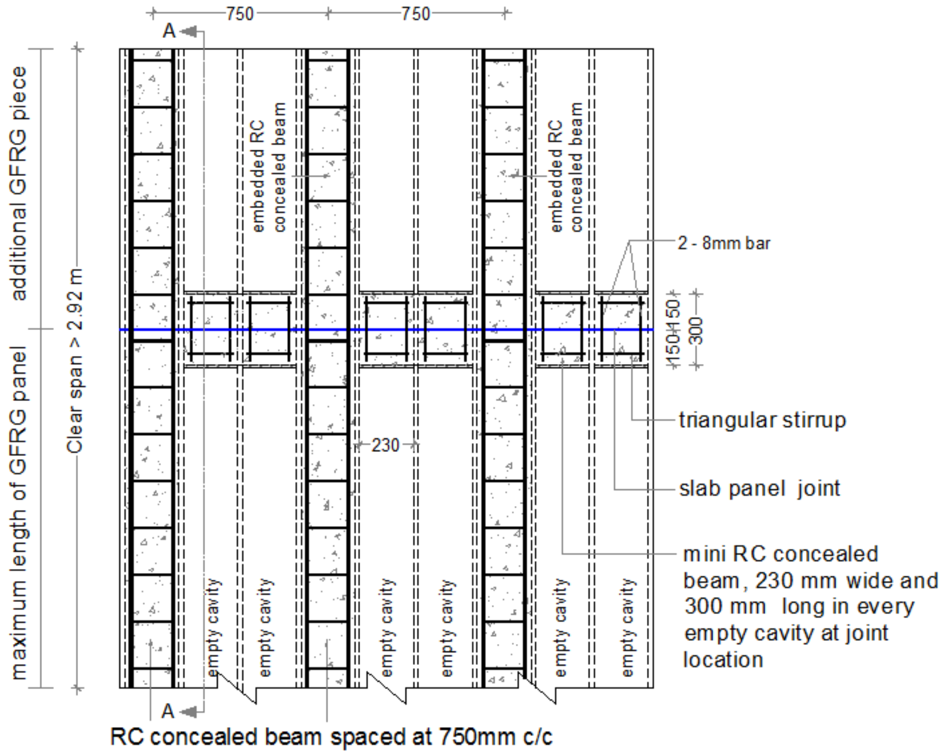


Fig. 47 GFRG slab: plan of bottom layer reinforcement

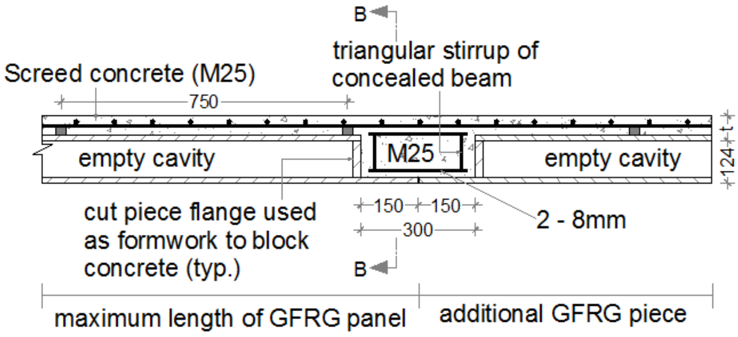


Fig. 48 Cross section A-A

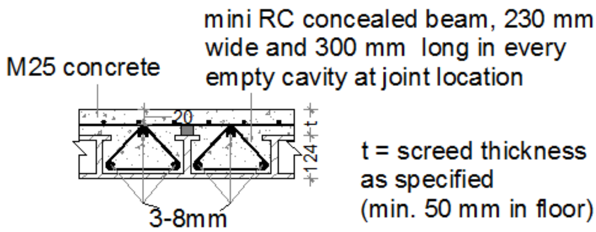


Fig. 49 Cross section B-B