

 SIMPLIFY STRUCTURAL ENGINEERING Head Office: Units 6-7, 6 Frederick Street, Wigston, Leicester, LE18 1PJ Tel: 0116 218 2917 Email: info@simplifyeng.co.uk We cover the Midlands, Milton Keynes, Watford and nearby areas, (for any other locations, additional travel charges may apply).	Project				Project Reference Number	
	163 The Park, Market Bosworth				S6133	
	Description				Sheet no./rev.	
Structural Calculations				1		
Prepared by	Date	Checked by	Date	Approved by	Date	
DB/NDP	09/10/2023	RS	09/10/2023	RS	09/10/2023	

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GENERAL NOTES

1. All dimensions are to be obtained or confirmed by the Contractor on site prior to construction. DO NOT SCALE FROM THESE DRAWINGS.
2. Construction work not to be started until calculations have been approved by Building Control.
3. All foundations, as per Building Control Officer requirements. Bearing strata under foundations to be capable of supporting a safe increased working load of 100 kN/m². Where necessary, in order to achieve the designated ground bearing capacity, pad foundations and strip footings shall be extended downward in grade C20 mass concrete.
4. All temporary works, eg. propping before/ during installing new beams, to be responsibility of the Contractor.
5. To minimise deflections of existing structure, new beams must be pinned up tight to existing construction with dry-pack mortar (1:3 cement: sharp sand, low water content), and all mortar allowed to cure prior to de-propping.
6. Due to significant structural works, minor post-construction deflection and cracking of brittle finishes may be expected in the existing building.
7. All works to be undertaken in accordance with the current Building Regulations Part A, British Standards and good building practice.
8. Beams and lintels to have a minimum bearing length of 100mm when perpendicular to the wall, and 200mm when parallel to the wall unless noted otherwise.
9. In vicinity of all new steel beams, masonry to be minimum - bricks solid 50N, block 7.3N. Mortar to be M4(iii) unless noted otherwise. Masonry repairs to match existing brick.
10. Any masonry/ brickwork/ foundations in vicinity of new structural members to be checked by the Contractor and replaced/ repaired, if defective.
11. All new steel columns/windposts to be fixed to existing/new masonry with M6x125mm resin-fixed threaded bars @ 300mm vertical c/c.
12. Where floor joists, flat roof joists & rafters span parallel to external cavity wall provide 30 x 5 thick galvanised MS straps at 1.5m centres. Straps to be turned over blockwork into cavity minimum 100mm and fixed to 3 No. joists ensuring solid noggins provided between joists and last joist is packed tight to inner leaf.
13. Wall plates to be strapped to wall using 30 x 5 thick galvanised MS straps at 1.5m centres.
14. Bonding of new external masonry to existing brickwork shall be by a 10mm straight joint with stainless steel crocodile wall ties or similar, plugged screwed to the existing wall. Joints are to be filled with closed cellular polyurethane packing material and faced with a flexible sealant.
15. Simplify Structural Engineering LLP have been instructed to produce structural design for the specific elements identified within calculations. We have not assessed any other elements of the structure.
16. CDM Regulations - Under the Construction (Design & Management) Regulations 2015 for commercial clients, the client duties apply in full. For Domestic clients, the client duties pass on to the Principal Contractor or Sole Contractor. For more information visit www.hse.gov.uk.

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	Prepared by DB/NDP	Date 09/10/2023	Checked by RS	Date 09/10/2023	Approved by RS	Date 09/10/2023	

Scope and Responsibilities of Parties Involved & Recommendations

- Structural Alteration Projects

Structural Engineer (SE) - Key Duties & Responsibilities:

- To provide reasonable skill and care to ensure that buildings are structurally safe - by sizing structural elements to support vertical and horizontal loads applied on buildings.
- To provide structural calculations and indicative structural mark-ups in a clear well-presented report format for the purpose of Building Control (BC) submission. Any requested clarifications from BC (allow up to 5 working days) regarding specified structural elements/calculations will be responded to without additional charges. The first two sets of correspondence from the Principal Contractor (experienced builder responsible for the project) will be responded free of charge, any further consulting or queries after the 12 month period will be charged at a hourly rate. We have not allowed for construction consulting unless stated otherwise.
- To provide additional consulting related to unforeseen conditions, hidden structural issues, or services which were not included within the initial scope of the agreed services. Additional fees to be quoted, and at least 5 working days should be allowed (builders should remove finishes, take measurements, and plan their work before ordering any structural elements).
- To provide standard connection details or connection loading information (connections could also be designed by a steel fabricator).

SE Optional services:

- The design of non-standard connection details (an additional fee to be quoted).
- The provision of overall construction consulting, with general guidance regarding compliance with Building Regulations to be provided by a Building Control Officer (BCO), an Approved Inspector (AI), or an Architect, if the consulting services agreed include construction support. If further consulting is requested, the SE may be able to provide further consulting services at an hourly rate.
- If the construction queries do not originate from the Principal Contractor and the client is self-managing the project, any construction advice provided will be charged on an hourly basis.

Services provided by others or not included on typical alteration projects:

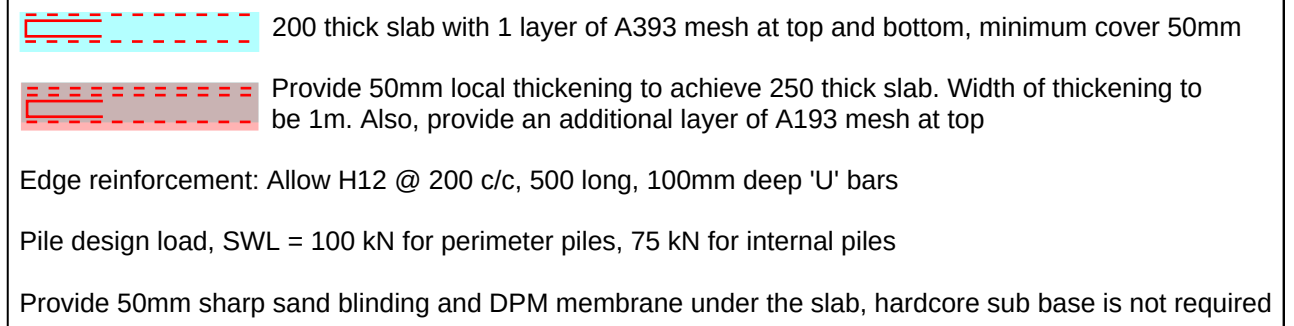
- The setting out information: including the lengths, whether steel is to be installed under or inside the ceiling, and other non-structural/appearance related requirements. These are to be agreed with a builder at site and/or an Architect should be engaged to provide further consulting services and prepare Architectural drawings.
- Intrusive inspections, with trial holes to be opened by builders working at an hourly rate, if requested. Any unforeseen structural issues should be reported to the SE by the BCO or the builder during construction once the finishes are removed.

Recommended Tasks by Client:

- To ensure that the builder (Principal Contractor) has relevant experience, with proof of experience provided of at least 5 similar projects. Each construction project is a team effort and requires experienced designers and contractors to ensure safety and minimise the risk of construction issues and unexpected costs. If a competent Principal Contractor with verified references is not appointed, Simplify Structural Engineering (SSE) will not be liable for any structural integrity defects and Health & Safety hazards.
- Appoint an Architect, if required.
- SSE proposals to be reviewed by the architect (if applicable) and contractor in-line with the proposal and site conditions prior to commencement of work but no longer than 12 months from the date of submission of the report. Any comments/discrepancies should be reported to the SE.
- Ensure the Building Control Officer or a private Approved Inspector is appointed before the start of the project.
- Work must not be started until the structural calculations are reviewed and approved by the BCO.
- Ensure that the Completion Certificate is issued by the BCO after completion.

Required Tasks by Builder:

- Ensure that all work is done safely, and that the applicable Health & Safety regulations are followed.
- Remove finishes (plaster, flooring, plaster board, etc.) and confirm assumptions before taking final measurements and before ordering of any proposed structural elements specified by the SE.
- Report to the BCO any issues with existing masonry or foundations, always plan for the unexpected and allow 10 working days for addressing any queries. It is important to check lead times with your BCO before the start of the project.
- Report to the SE if any unforeseen structural issues are exposed including presence of existing drainage pipes. As above, plan for the unexpected and allow up to 5 working days for addressing any questions, as an emergency service response time might not be feasible.
- Repair and replace any weak or defective masonry which is near the proposed structural elements.
- Coordinate and schedule site inspection(s) with the BCO before ordering any steel.
- Measure the clear span of openings and add a minimum of 200mm on each side (400mm in total) if the walls are parallel, and a minimum of 100mm on each side (200mm in total) if the walls are perpendicular. The longer the bearings the better, if the space allows.
- Where a new external wall adjoins the existing one, if possible, a movement joint should be formed using suitable wall starters and filled with flexible sealant. Any internal masonry should be tooth into existing or connected using suitable wall starters. Any timber frame partitions should be dowelled to the existing wall using suitable fixings and/or ties at 300mm c/c.
- Where new foundations adjoin existing, the new foundations should be dowelled into the existing using M20x400mm long resin-fixed dowels @ 200mm centre on centre (c/c) unless specified otherwise.
- Confirm any assumptions made by the SE, which should be stated in the SE report/drawings. Report discrepancies or any discovered/exposed structural elements that require support. For example, if a beam width does not match the walls above/below, the specification of an additional shelf plate, top plate, or a different type of beam might be required before steel ordering. Any unsupported masonry should not project more than 25mm.
- Discuss with clients the exact steel placement before ordering, and illustrate using measuring tape or a plywood mock-up template. This will check whether the client has any unaddressed requirements related to the final appearance. If the client has very strict requirements regarding the final appearance, and it cannot be agreed at site, detailed construction drawings may be required by an Architect.
- Install temporary supports (acrow props, needle beams, etc.) before removal of any structural elements.
- Order steelwork, padstones and/or solid engineering bricks.
- Schedule the BCO inspection of any excavations and agree foundations depth with the BCO before the pouring of any concrete.
- Install structural elements and schedule the BCO inspection before finishing the installation.
- Implement additional repairs if requested by the BCO.
- Ensure that a Completion Certificate is issued by the BCO after completion.



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Garage loading:-

Floor dead load = 5 kN/m^2 (concrete floor)

Live load = 5 kN/m^2 .

Roof Dead load = 1.2 kN/m^2

Live load = 0.75 kN/m^2 .

Wall load, Single skin = $3.2 \text{ kN/m}^2 \times 2.1 \text{ m}$
 (Say 150 thick)
 = 7 kN/m

Load take down for end strip:-

Line load from wall:-

→ wall DL = 7 kN/m

→ Roof DL = $1.2 \text{ kN/m}^2 \times \frac{7.5}{2} = 4.5 \text{ kN/m}$

→ Roof LL = $0.75 \text{ kN/m}^2 \times \frac{7.5}{2} = 2.8 \text{ kN/m}$

floor load on 1m width of strip,

dead load = 5 kN/m

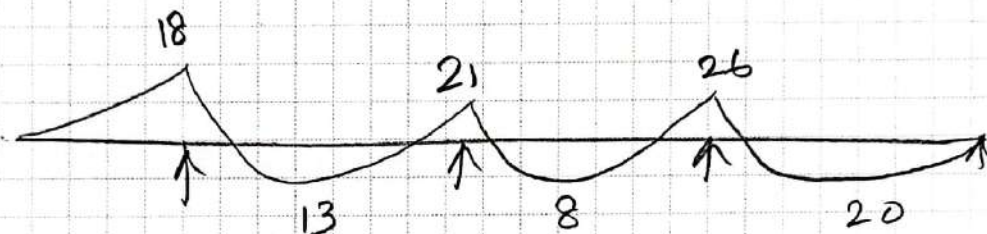
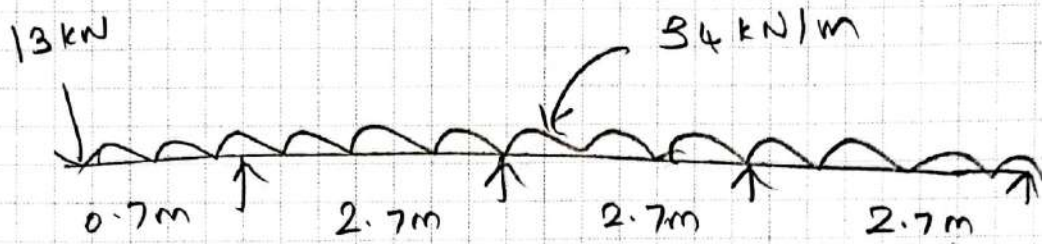
Live load = 5 kN/m

Total DL = $5 \text{ kN/m} + 7 \text{ kN/m} + 4.5 \text{ kN/m} = 16.5 \text{ kN/m}$

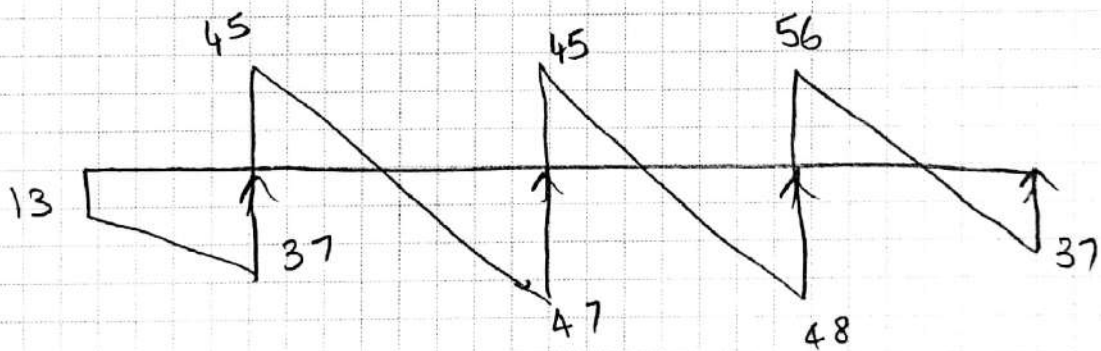
Total LL = $5 \text{ kN/m} + 2.8 \text{ kN/m} = 7.8 \text{ kN/m}$

ULS = 34 kN/m

Project Address:	Additional Information:	Project No. S6133	Page No. ②
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Bending Moment (kN.m)



Shear force (kN)

- 250 thick slab in C32 concrete,
- provide A393 mesh @ top and bottom + 1 Layer of A193 mesh @ top.

Project GARAGE				Job no. S6133	
Calcs for SLAB DESIGN- for end strip				Start page no./Revision 3	
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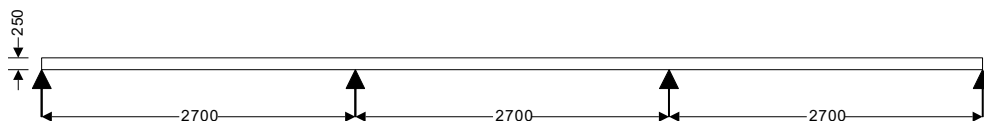
RC SLAB DESIGN

In accordance with EN1992-1-1:2004 incorporating corrigendum January 2008 and the UK national annex

Tedds calculation version 1.0.21

Design summary

Description	Unit	Provided	Required	Utilisation	Result
Support 1					
Tension reinf.	mm ² /m	585	338	0.577	PASS
Tension bar spacing	mm	100	300	0.333	PASS
Shear	kN/m	117.2	82.0	0.700	PASS
Span 1					
Tension reinf.	mm ² /m	393	322	0.820	PASS
Tension bar spacing	mm	200	300	0.667	PASS
Allow. span-to-depth ratio		13.17	52.00	0.253	PASS
Support 2					
Tension reinf.	mm ² /m	585	338	0.577	PASS
Tension bar spacing	mm	100	300	0.333	PASS
Shear	kN/m	117.2	92.0	0.785	PASS
Span 2					
Tension reinf.	mm ² /m	393	322	0.820	PASS
Tension bar spacing	mm	200	300	0.667	PASS
Allow. span-to-depth ratio		13.17	60.00	0.220	PASS
Support 3					
Tension reinf.	mm ² /m	585	338	0.577	PASS
Tension bar spacing	mm	100	283	0.354	PASS
Shear	kN/m	117.2	110.0	0.939	PASS
Span 3					
Tension reinf.	mm ² /m	393	322	0.820	PASS
Tension bar spacing	mm	200	239	0.838	PASS
Allow. span-to-depth ratio		13.17	52.00	0.253	PASS
Support 4					
Tension reinf.	mm ² /m	393	338	0.861	PASS
Tension bar spacing	mm	200	300	0.667	PASS
Shear	kN/m	113.7	40.0	0.352	PASS
Cover					
Min cover top	mm	30	20	0.667	PASS
Min cover bottom	mm	40	20	0.500	PASS



Slab definition

Slab reference name

garage slab

Overall slab depth

h = 250 mm

Number of spans

N_{spans} = 3

First support

Monolithic

Last support

Simple

Nominal cover to top reinforcement

C_{nom_t} = 30 mm

Nominal cover to bottom reinforcement

C_{nom_b} = 40 mm

Loading

Ratio of quasi-permanent to ultimate load

r_q = 0.800

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SLAB DESIGN- for end strip				4	
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Concrete properties

Concrete strength class	C32/40
Characteristic cylinder strength	$f_{ck} = 32 \text{ N/mm}^2$
Partial factor (Table 2.1N)	$\gamma_c = 1.50$
Compressive strength factor (cl. 3.1.6)	$\alpha_{cc} = 0.85$
Design compressive strength (cl. 3.1.6)	$f_{cd} = 18.1 \text{ N/mm}^2$
Mean axial tensile strength (Table 3.1)	$f_{ctm} = 0.30 \text{ N/mm}^2 \times (f_{ck} / 1 \text{ N/mm}^2)^{2/3} = 3.0 \text{ N/mm}^2$
Maximum aggregate size	$d_g = 20 \text{ mm}$

Reinforcement properties

Characteristic yield strength	$f_{yk} = 500 \text{ N/mm}^2$
Partial factor (Table 2.1N)	$\gamma_s = 1.15$
Design yield strength (fig. 3.8)	$f_{yd} = f_{yk} / \gamma_s = 434.8 \text{ N/mm}^2$

Concrete cover to reinforcement

Nominal cover to top reinforcement	$c_{nom_t} = 30 \text{ mm}$
Nominal cover to bottom reinforcement	$c_{nom_b} = 40 \text{ mm}$
Fire resistance period to top of slab	$R_{top} = 30 \text{ min}$
Fire resistance period to bottom of slab	$R_{btm} = 30 \text{ min}$
Axis distance to top reinf (Table 5.8)	$a_{fi_t} = 10 \text{ mm}$
Axis distance to bottom reinf (Table 5.8)	$a_{fi_b} = 10 \text{ mm}$
Max bar diameter in top	$\phi_{max_t} = 10 \text{ mm}$
Max bar diameter in bottom	$\phi_{max_b} = 10 \text{ mm}$
Min. top cover requirement with regard to bond	$c_{min,b_t} = \phi_{max_t} = 10 \text{ mm}$
Min. btm cover requirement with regard to bond	$c_{min,b_b} = \phi_{max_b} = 10 \text{ mm}$
Reinforcement fabrication	Not subject to QA system
Cover allowance for deviation	$\Delta C_{dev} = 10 \text{ mm}$
Min. required nominal cover to top reinf	$c_{nom_t_min} = \max(a_{fi_t} - \phi_{max_t} / 2, c_{min,b_t} + \Delta C_{dev}) = 20.0 \text{ mm}$
Min. required nominal cover to bottom reinf	$c_{nom_b_min} = \max(a_{fi_b} - \phi_{max_b} / 2, c_{min,b_b} + \Delta C_{dev}) = 20.0 \text{ mm}$

PASS - There is sufficient cover to the top reinforcement
PASS - There is sufficient cover to the bottom reinforcement

Bending design checks

Redistribution ratio	$\delta = 1.0$
Limiting value of K	$K' = 0.598 \times \delta - 0.18 \times \delta^2 - 0.21 = 0.208$

Reinforcement design at midspan of span 1 (cl.6.1)

Length of span 1	$l_1 = 2700 \text{ mm}$
Design bending moment	$M_{p1} = 15.0 \text{ kNm/m}$
Reinforcement provided	A393 mesh
Area provided	$A_{sp1} = 393 \text{ mm}^2/\text{m}$
Effective depth to tension reinforcement	$d_{p1} = h - c_{nom_b} - \phi_{p1} / 2 = 205.0 \text{ mm}$
K factor	$K = M_{p1} / (b \times d_{p1}^2 \times f_{ck}) = 0.011$
	$K < K'$ - Compression reinforcement is not required
Lever arm	$z = \min(0.95 \times d_{p1}, d_{p1} / 2 \times (1 + \sqrt{1 - 3.53 \times K}))$ $z = 194.7 \text{ mm}$
Area of reinforcement required for bending	$A_{sp1_m} = M_{p1} / (f_{yd} \times z) = 177 \text{ mm}^2/\text{m}$
Minimum area required	$A_{sp1_min} = \max(0.26 \times (f_{ctm}/f_{yk}), 0.0013) \times b \times d_{p1} = 322 \text{ mm}^2/\text{m}$
Area of reinforcement required	$A_{sp1_req} = \max(A_{sp1_m}, A_{sp1_min}) = 322 \text{ mm}^2/\text{m}$

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PASS - Area of tension reinforcement provided is adequate (0.820)

Check reinforcement spacing

Reinforcement service stress
Maximum allowable spacing (Table 7.3N)
Actual bar spacing

$$\sigma_s = (f_{yk} / \gamma_s) \times \min((A_{sp1_m}/A_{sp1}), 1.0) \times r_q = \mathbf{156.8 \text{ N/mm}^2}$$

$$s_{max_p1} = \mathbf{300 \text{ mm}}$$

$$s_{p1} = \mathbf{200 \text{ mm}}$$

PASS - The reinforcement spacing is acceptable

Reinforcement design at midspan of span 2 (cl.6.1)

Length of span 2
Design bending moment
Reinforcement provided
Area provided
Effective depth to tension reinforcement
K factor

$$l_2 = \mathbf{2700 \text{ mm}}$$

$$M_{p2} = \mathbf{8.0 \text{ kNm/m}}$$

$$\mathbf{A393 \text{ mesh}}$$

$$A_{sp2} = \mathbf{393 \text{ mm}^2/\text{m}}$$

$$d_{p2} = h - c_{nom_b} - \phi_{p2} / 2 = \mathbf{205.0 \text{ mm}}$$

$$K = M_{p2} / (b \times d_{p2}^2 \times f_{ck}) = \mathbf{0.006}$$

K < K' - Compression reinforcement is not required

Lever arm

$$z = \min(0.95 \times d_{p2}, d_{p2} / 2 \times (1 + \sqrt{(1 - 3.53 \times K)}))$$

$$z = \mathbf{194.7 \text{ mm}}$$

Area of reinforcement required for bending
Minimum area required
Area of reinforcement required

$$A_{sp2_m} = M_{p2} / (f_{yd} \times z) = \mathbf{94 \text{ mm}^2/\text{m}}$$

$$A_{sp2_min} = \max(0.26 \times (f_{ctm}/f_{yk}), 0.0013) \times b \times d_{p2} = \mathbf{322 \text{ mm}^2/\text{m}}$$

$$A_{sp2_req} = \max(A_{sp2_m}, A_{sp2_min}) = \mathbf{322 \text{ mm}^2/\text{m}}$$

PASS - Area of tension reinforcement provided is adequate (0.820)

Check reinforcement spacing

Reinforcement service stress
Maximum allowable spacing (Table 7.3N)
Actual bar spacing

$$\sigma_s = (f_{yk} / \gamma_s) \times \min((A_{sp2_m}/A_{sp2}), 1.0) \times r_q = \mathbf{83.6 \text{ N/mm}^2}$$

$$s_{max_p2} = \mathbf{300 \text{ mm}}$$

$$s_{p2} = \mathbf{200 \text{ mm}}$$

PASS - The reinforcement spacing is acceptable

Reinforcement design at midspan of span 3 (cl.6.1)

Length of span 3
Design bending moment
Reinforcement provided
Area provided
Effective depth to tension reinforcement
K factor

$$l_3 = \mathbf{2700 \text{ mm}}$$

$$M_{p3} = \mathbf{20.0 \text{ kNm/m}}$$

$$\mathbf{A393 \text{ mesh}}$$

$$A_{sp3} = \mathbf{393 \text{ mm}^2/\text{m}}$$

$$d_{p3} = h - c_{nom_b} - \phi_{p3} / 2 = \mathbf{205.0 \text{ mm}}$$

$$K = M_{p3} / (b \times d_{p3}^2 \times f_{ck}) = \mathbf{0.015}$$

K < K' - Compression reinforcement is not required

Lever arm

$$z = \min(0.95 \times d_{p3}, d_{p3} / 2 \times (1 + \sqrt{(1 - 3.53 \times K)}))$$

$$z = \mathbf{194.7 \text{ mm}}$$

Area of reinforcement required for bending
Minimum area required
Area of reinforcement required

$$A_{sp3_m} = M_{p3} / (f_{yd} \times z) = \mathbf{236 \text{ mm}^2/\text{m}}$$

$$A_{sp3_min} = \max(0.26 \times (f_{ctm}/f_{yk}), 0.0013) \times b \times d_{p3} = \mathbf{322 \text{ mm}^2/\text{m}}$$

$$A_{sp3_req} = \max(A_{sp3_m}, A_{sp3_min}) = \mathbf{322 \text{ mm}^2/\text{m}}$$

PASS - Area of tension reinforcement provided is adequate (0.820)

Check reinforcement spacing

Reinforcement service stress
Maximum allowable spacing (Table 7.3N)
Actual bar spacing

$$\sigma_s = (f_{yk} / \gamma_s) \times \min((A_{sp3_m}/A_{sp3}), 1.0) \times r_q = \mathbf{209.0 \text{ N/mm}^2}$$

$$s_{max_p3} = \mathbf{239 \text{ mm}}$$

$$s_{p3} = \mathbf{200 \text{ mm}}$$

PASS - The reinforcement spacing is acceptable

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Reinforcement design at support 1 (cl.6.1)

Design bending moment

$$M_{n1} = 19.0 \text{ kNm/m}$$

Reinforcement provided

A393 mesh + 7 mm dia. bars at 200 mm centres

Area provided

$$A_{sn1} = 585 \text{ mm}^2/\text{m}$$

Effective depth to tension reinforcement

$$d_{n1} = h - c_{nom_t} - \phi_{n1} / 2 = 215.0 \text{ mm}$$

K factor

$$K = M_{n1} / (b \times d_{n1}^2 \times f_{ck}) = 0.013$$

K < K' - Compression reinforcement is not required

Lever arm

$$z = \min(0.95 \times d_{n1}, d_{n1} / 2 \times (1 + \sqrt{(1 - 3.53 \times K)}))$$

$$z = 204.2 \text{ mm}$$

Area of reinforcement required for bending

$$A_{sn1_m} = M_{n1} / (f_{yd} \times z) = 214 \text{ mm}^2/\text{m}$$

Minimum area required

$$A_{sn1_min} = \max(0.26 \times (f_{ctm}/f_{yk}), 0.0013) \times b \times d_{n1} = 338 \text{ mm}^2/\text{m}$$

Area of reinforcement required

$$A_{sn1_req} = \max(A_{sn1_m}, A_{sn1_min}) = 338 \text{ mm}^2/\text{m}$$

PASS - Area of tension reinforcement provided is adequate (0.577)

Check reinforcement spacing

Reinforcement service stress

$$\sigma_s = (f_{yk} / \gamma_s) \times \min((A_{sn1_m}/A_{sn1}), 1.0) \times r_q = 127.1 \text{ N/mm}^2$$

Maximum allowable spacing (Table 7.3N)

$$s_{max_n1} = 300 \text{ mm}$$

Actual bar spacing

$$s_{n1} = 100 \text{ mm}$$

PASS - The reinforcement spacing is acceptable

Reinforcement design at support 2 (cl.6.1)

Design bending moment

$$M_{n2} = 21.0 \text{ kNm/m}$$

Reinforcement provided

A393 mesh + 7 mm dia. bars at 200 mm centres

Area provided

$$A_{sn2} = 585 \text{ mm}^2/\text{m}$$

Effective depth to tension reinforcement

$$d_{n2} = h - c_{nom_t} - \phi_{n2} / 2 = 215.0 \text{ mm}$$

K factor

$$K = M_{n2} / (b \times d_{n2}^2 \times f_{ck}) = 0.014$$

K < K' - Compression reinforcement is not required

Lever arm

$$z = \min(0.95 \times d_{n2}, d_{n2} / 2 \times (1 + \sqrt{(1 - 3.53 \times K)}))$$

$$z = 204.2 \text{ mm}$$

Area of reinforcement required for bending

$$A_{sn2_m} = M_{n2} / (f_{yd} \times z) = 236 \text{ mm}^2/\text{m}$$

Minimum area required

$$A_{sn2_min} = \max(0.26 \times (f_{ctm}/f_{yk}), 0.0013) \times b \times d_{n2} = 338 \text{ mm}^2/\text{m}$$

Area of reinforcement required

$$A_{sn2_req} = \max(A_{sn2_m}, A_{sn2_min}) = 338 \text{ mm}^2/\text{m}$$

PASS - Area of tension reinforcement provided is adequate (0.577)

Check reinforcement spacing

Reinforcement service stress

$$\sigma_s = (f_{yk} / \gamma_s) \times \min((A_{sn2_m}/A_{sn2}), 1.0) \times r_q = 140.5 \text{ N/mm}^2$$

Maximum allowable spacing (Table 7.3N)

$$s_{max_n2} = 300 \text{ mm}$$

Actual bar spacing

$$s_{n2} = 100 \text{ mm}$$

PASS - The reinforcement spacing is acceptable

Reinforcement design at support 3 (cl.6.1)

Design bending moment

$$M_{n3} = 26.0 \text{ kNm/m}$$

Reinforcement provided

A393 mesh + 7 mm dia. bars at 200 mm centres

Area provided

$$A_{sn3} = 585 \text{ mm}^2/\text{m}$$

Effective depth to tension reinforcement

$$d_{n3} = h - c_{nom_t} - \phi_{n3} / 2 = 215.0 \text{ mm}$$

K factor

$$K = M_{n3} / (b \times d_{n3}^2 \times f_{ck}) = 0.018$$

K < K' - Compression reinforcement is not required

Lever arm

$$z = \min(0.95 \times d_{n3}, d_{n3} / 2 \times (1 + \sqrt{(1 - 3.53 \times K)}))$$

$$z = 204.2 \text{ mm}$$

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Area of reinforcement required for bending

$$A_{sn3_m} = M_{n3} / (f_{yd} \times z) = \mathbf{293 \text{ mm}^2/m}$$

Minimum area required

$$A_{sn3_min} = \max(0.26 \times (f_{ctm}/f_{yk}), 0.0013) \times b \times d_{n3} = \mathbf{338 \text{ mm}^2/m}$$

Area of reinforcement required

$$A_{sn3_req} = \max(A_{sn3_m}, A_{sn3_min}) = \mathbf{338 \text{ mm}^2/m}$$

PASS - Area of tension reinforcement provided is adequate (0.577)

Check reinforcement spacing

Reinforcement service stress

$$\sigma_s = (f_{yk} / \gamma_s) \times \min((A_{sn3_m}/A_{sn3}), 1.0) \times r_q = \mathbf{174.0 \text{ N/mm}^2}$$

Maximum allowable spacing (Table 7.3N)

$$s_{max_n3} = \mathbf{283 \text{ mm}}$$

Actual bar spacing

$$s_{n3} = \mathbf{100 \text{ mm}}$$

PASS - The reinforcement spacing is acceptable

Shear design checks

Shear resistance constant (cl. 6.2.2)

$$C_{Rd,c} = 0.18 \text{ N/mm}^2 / \gamma_c = \mathbf{0.12 \text{ N/mm}^2}$$

Shear capacity check at support 1

Shear force

$$V_1 = \mathbf{82.0 \text{ kN/m}}$$

Effective depth factor (cl. 6.2.2)

$$k = \min(2.0, 1 + (200 \text{ mm} / d_{n1})^{0.5}) = \mathbf{1.964}$$

Reinforcement ratio

$$\rho_l = \min(0.02, A_{sn1} / (b \times d_{n1})) = \mathbf{0.0027}$$

Minimum shear resistance (Exp. 6.3N)

$$V_{Rd,c_min} = 0.035 \text{ N/mm}^2 \times k^{1.5} \times (f_{ck} / 1 \text{ N/mm}^2)^{0.5} \times b \times d_{n1}$$

$$V_{Rd,c_min} = \mathbf{117.2 \text{ kN/m}}$$

Shear resistance (Exp. 6.2a)

$$V_{Rd,c1} = \max(V_{Rd,c_min}, C_{Rd,c} \times k \times (100 \times \rho_l \times (f_{ck}/1 \text{ N/mm}^2))^{0.333} \times b \times d_{n1})$$

$$V_{Rd,c1} = \mathbf{117.2 \text{ kN/m}}$$

PASS - Shear capacity is adequate (0.700)

Shear capacity check at support 2

Shear force

$$V_2 = \mathbf{92.0 \text{ kN/m}}$$

Effective depth factor (cl. 6.2.2)

$$k = \min(2.0, 1 + (200 \text{ mm} / d_{n2})^{0.5}) = \mathbf{1.964}$$

Reinforcement ratio

$$\rho_l = \min(0.02, A_{sn2} / (b \times d_{n2})) = \mathbf{0.0027}$$

Minimum shear resistance (Exp. 6.3N)

$$V_{Rd,c_min} = 0.035 \text{ N/mm}^2 \times k^{1.5} \times (f_{ck} / 1 \text{ N/mm}^2)^{0.5} \times b \times d_{n2}$$

$$V_{Rd,c_min} = \mathbf{117.2 \text{ kN/m}}$$

Shear resistance (Exp. 6.2a)

$$V_{Rd,c2} = \max(V_{Rd,c_min}, C_{Rd,c} \times k \times (100 \times \rho_l \times (f_{ck}/1 \text{ N/mm}^2))^{0.333} \times b \times d_{n2})$$

$$V_{Rd,c2} = \mathbf{117.2 \text{ kN/m}}$$

PASS - Shear capacity is adequate (0.785)

Shear capacity check at support 3

Shear force

$$V_3 = \mathbf{110.0 \text{ kN/m}}$$

Effective depth factor (cl. 6.2.2)

$$k = \min(2.0, 1 + (200 \text{ mm} / d_{n3})^{0.5}) = \mathbf{1.964}$$

Reinforcement ratio

$$\rho_l = \min(0.02, A_{sn3} / (b \times d_{n3})) = \mathbf{0.0027}$$

Minimum shear resistance (Exp. 6.3N)

$$V_{Rd,c_min} = 0.035 \text{ N/mm}^2 \times k^{1.5} \times (f_{ck} / 1 \text{ N/mm}^2)^{0.5} \times b \times d_{n3}$$

$$V_{Rd,c_min} = \mathbf{117.2 \text{ kN/m}}$$

Shear resistance (Exp. 6.2a)

$$V_{Rd,c3} = \max(V_{Rd,c_min}, C_{Rd,c} \times k \times (100 \times \rho_l \times (f_{ck}/1 \text{ N/mm}^2))^{0.333} \times b \times d_{n3})$$

$$V_{Rd,c3} = \mathbf{117.2 \text{ kN/m}}$$

PASS - Shear capacity is adequate (0.939)

Shear capacity check at support 4

Shear force

$$V_4 = \mathbf{40.0 \text{ kN/m}}$$

Reinforcement provided

$$\mathbf{A393 \text{ mesh}}$$

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Area provided $A_{sd4} = 393 \text{ mm}^2/\text{m}$
Effective depth $d_{d4} = h - c_{nom_b} - \phi_{d4} / 2 = 205.0 \text{ mm}$
Effective depth factor (cl. 6.2.2) $k = \min(2.0, 1 + (200 \text{ mm} / d_{d4})^{0.5}) = 1.988$
Reinforcement ratio $\rho_l = \min(0.02, A_{sd4} / (b \times d_{d4})) = 0.0019$
Minimum shear resistance (Exp. 6.3N) $V_{Rd,c_min} = 0.035 \text{ N/mm}^2 \times k^{1.5} \times (f_{ck} / 1 \text{ N/mm}^2)^{0.5} \times b \times d_{d4}$
 $V_{Rd,c_min} = 113.7 \text{ kN/m}$
Shear resistance (Exp. 6.2a) $V_{Rd,c4} = \max(V_{Rd,c_min}, C_{Rd,c} \times k \times (100 \times \rho_l \times (f_{ck} / 1 \text{ N/mm}^2))^{0.333} \times b \times d_{d4})$
 $V_{Rd,c4} = 113.7 \text{ kN/m}$

PASS - Shear capacity is adequate (0.352)

Deflection checks

Basic span-to-depth ratio deflection check span 1 (cl. 7.4.2)

Reference reinforcement ratio $\rho_0 = (f_{ck} / 1 \text{ N/mm}^2)^{0.5} / 1000 = 0.0057$
Required tension reinforcement ratio $\rho = \max(0.0035, A_{sp1_m} / (b \times d_{p1})) = 0.0035$
Required compression reinforcement ratio $\rho' = A_{scp1_req} / (b \times d_{p1}) = 0.0000$
Structural system factor (Table 7.4N) $K_\delta = 1.3$
Basic span-to-depth ratio limit $ratio_{lim1_bas} = K_\delta \times [11 + 1.5 \times (f_{ck} / 1 \text{ N/mm}^2)^{0.5} \times \rho_0 / \rho + 3.2 \times (f_{ck} / 1 \text{ N/mm}^2)^{0.5} \times (\rho_0 / \rho - 1)^{1.5}]$
(Exp. 7.16a) $ratio_{lim1_bas} = 43.51$
Modified span-to-depth ratio limit
 $ratio_{lim1} = \min(40 \times K_\delta, \min(1.5, (500 \text{ N/mm}^2 / f_{yk}) \times (A_{sp1} / A_{sp1_m})) \times ratio_{lim1_bas}) = 52.00$
Actual span-to-depth ratio $ratio_{act1} = l_1 / d_{p1} = 13.17$

PASS - Span-to-depth ratio is acceptable (0.253)

Basic span-to-depth ratio deflection check span 2 (cl. 7.4.2)

Reference reinforcement ratio $\rho_0 = (f_{ck} / 1 \text{ N/mm}^2)^{0.5} / 1000 = 0.0057$
Required tension reinforcement ratio $\rho = \max(0.0035, A_{sp2_m} / (b \times d_{p2})) = 0.0035$
Required compression reinforcement ratio $\rho' = A_{scp2_req} / (b \times d_{p2}) = 0.0000$
Structural system factor (Table 7.4N) $K_\delta = 1.5$
Basic span-to-depth ratio limit $ratio_{lim2_bas} = K_\delta \times [11 + 1.5 \times (f_{ck} / 1 \text{ N/mm}^2)^{0.5} \times \rho_0 / \rho + 3.2 \times (f_{ck} / 1 \text{ N/mm}^2)^{0.5} \times (\rho_0 / \rho - 1)^{1.5}]$
(Exp. 7.16a) $ratio_{lim2_bas} = 50.21$
Modified span-to-depth ratio limit
 $ratio_{lim2} = \min(40 \times K_\delta, \min(1.5, (500 \text{ N/mm}^2 / f_{yk}) \times (A_{sp2} / A_{sp2_m})) \times ratio_{lim2_bas}) = 60.00$
Actual span-to-depth ratio $ratio_{act2} = l_2 / d_{p2} = 13.17$

PASS - Span-to-depth ratio is acceptable (0.220)

Basic span-to-depth ratio deflection check span 3 (cl. 7.4.2)

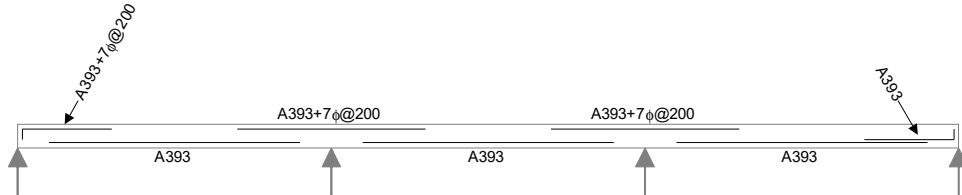
Reference reinforcement ratio $\rho_0 = (f_{ck} / 1 \text{ N/mm}^2)^{0.5} / 1000 = 0.0057$
Required tension reinforcement ratio $\rho = \max(0.0035, A_{sp3_m} / (b \times d_{p3})) = 0.0035$
Required compression reinforcement ratio $\rho' = A_{scp3_req} / (b \times d_{p3}) = 0.0000$
Structural system factor (Table 7.4N) $K_\delta = 1.3$
Basic span-to-depth ratio limit $ratio_{lim3_bas} = K_\delta \times [11 + 1.5 \times (f_{ck} / 1 \text{ N/mm}^2)^{0.5} \times \rho_0 / \rho + 3.2 \times (f_{ck} / 1 \text{ N/mm}^2)^{0.5} \times (\rho_0 / \rho - 1)^{1.5}]$
(Exp. 7.16a) $ratio_{lim3_bas} = 43.51$
Modified span-to-depth ratio limit
 $ratio_{lim3} = \min(40 \times K_\delta, \min(1.5, (500 \text{ N/mm}^2 / f_{yk}) \times (A_{sp3} / A_{sp3_m})) \times ratio_{lim3_bas}) = 52.00$
Actual span-to-depth ratio $ratio_{act3} = l_3 / d_{p3} = 13.17$

PASS - Span-to-depth ratio is acceptable (0.253)

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Reinforcement sketch

The following sketch is indicative only. Note that additional reinforcement may be required in accordance with clauses 9.2.1.2, 9.2.1.4 and 9.2.1.5 of EN 1992-1-1:2004 to meet detailing rules.



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Load Takedown - Middle strip/m width:-

Point load:-

wall load = 7 kN/m.

Roof dead load = 1.2 kN/m

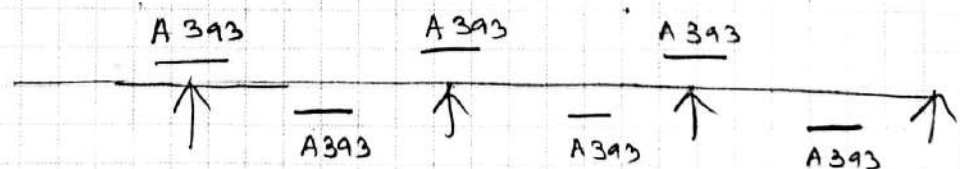
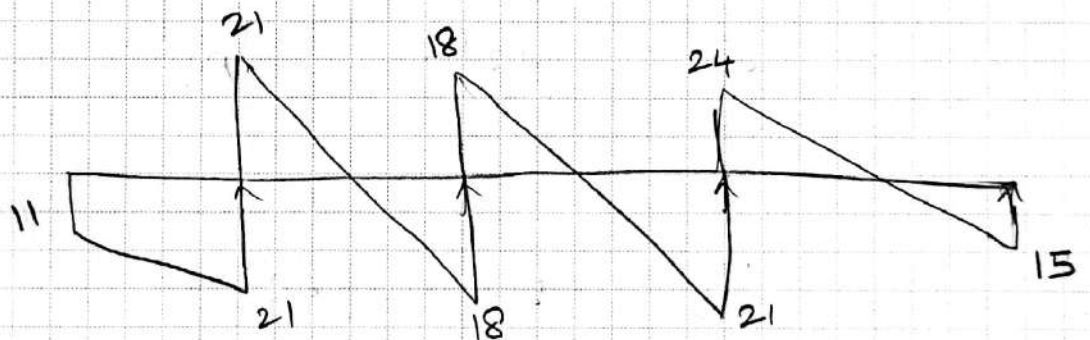
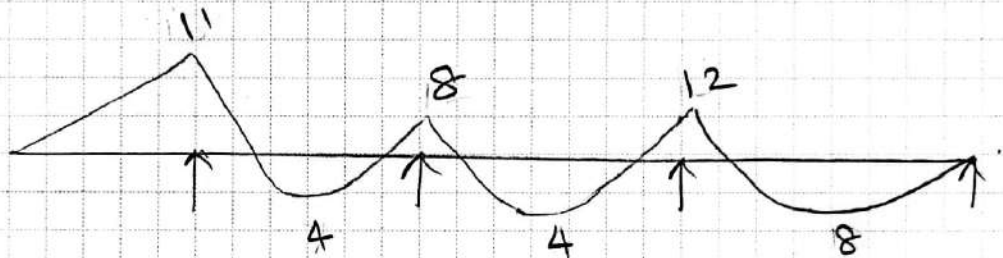
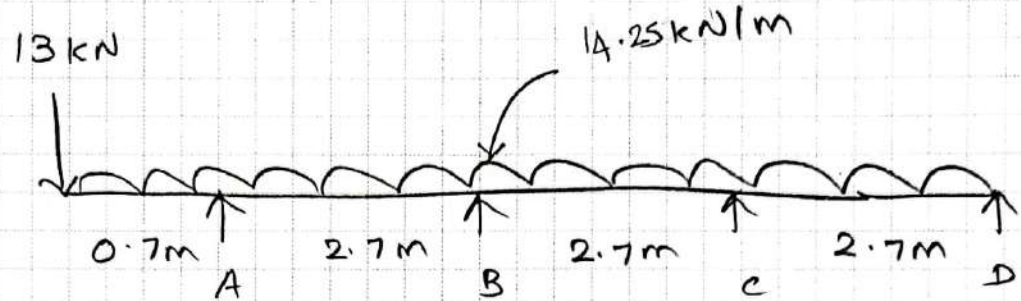
Roof live load = 0.75 kN/m.

} 8.2 kN/m

floor dead load = 5 kN/m

floor live load = 5 kN/m

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— 150 thick RC slab, 9M C32 concrete, with 1 layer of A393 mesh @ top and bottom

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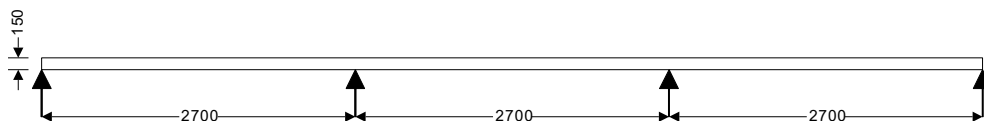
RC SLAB DESIGN

In accordance with EN1992-1-1:2004 incorporating corrigendum January 2008 and the UK national annex

Tedds calculation version 1.0.21

Design summary

Description	Unit	Provided	Required	Utilisation	Result
Support 1					
Tension reinf.	mm ² /m	393	232	0.589	PASS
Tension bar spacing	mm	200	244	0.820	PASS
Shear	kN/m	64.4	45.0	0.699	PASS
Span 1					
Tension reinf.	mm ² /m	393	165	0.420	PASS
Tension bar spacing	mm	200	300	0.667	PASS
Allow. span-to-depth ratio		25.71	52.00	0.495	PASS
Support 2					
Tension reinf.	mm ² /m	393	181	0.460	PASS
Tension bar spacing	mm	200	300	0.667	PASS
Shear	kN/m	64.4	40.0	0.621	PASS
Span 2					
Tension reinf.	mm ² /m	393	165	0.420	PASS
Tension bar spacing	mm	200	300	0.667	PASS
Allow. span-to-depth ratio		25.71	60.00	0.429	PASS
Support 3					
Tension reinf.	mm ² /m	393	253	0.643	PASS
Tension bar spacing	mm	200	221	0.907	PASS
Shear	kN/m	64.4	45.0	0.699	PASS
Span 3					
Tension reinf.	mm ² /m	393	184	0.469	PASS
Tension bar spacing	mm	200	296	0.676	PASS
Allow. span-to-depth ratio		25.71	52.00	0.495	PASS
Support 4					
Tension reinf.	mm ² /m	393	338	0.861	PASS
Tension bar spacing	mm	200	300	0.667	PASS
Shear	kN/m	58.8	15.0	0.255	PASS
Cover					
Min cover top	mm	30	20	0.667	PASS
Min cover bottom	mm	40	20	0.500	PASS



Slab definition

Slab reference name

garage slab

Overall slab depth

h = 150 mm

Number of spans

N_{spans} = 3

First support

Monolithic

Last support

Simple

Nominal cover to top reinforcement

c_{nom_t} = 30 mm

Nominal cover to bottom reinforcement

c_{nom_b} = 40 mm

Loading

Ratio of quasi-permanent to ultimate load

r_q = 0.800

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NDP	04/10/2023	RS	04/10/2023	RS	04/10/2023

Concrete properties

Concrete strength class	C32/40
Characteristic cylinder strength	$f_{ck} = 32 \text{ N/mm}^2$
Partial factor (Table 2.1N)	$\gamma_c = 1.50$
Compressive strength factor (cl. 3.1.6)	$\alpha_{cc} = 0.85$
Design compressive strength (cl. 3.1.6)	$f_{cd} = 18.1 \text{ N/mm}^2$
Mean axial tensile strength (Table 3.1)	$f_{ctm} = 0.30 \text{ N/mm}^2 \times (f_{ck} / 1 \text{ N/mm}^2)^{2/3} = 3.0 \text{ N/mm}^2$
Maximum aggregate size	$d_g = 20 \text{ mm}$

Reinforcement properties

Characteristic yield strength	$f_{yk} = 500 \text{ N/mm}^2$
Partial factor (Table 2.1N)	$\gamma_s = 1.15$
Design yield strength (fig. 3.8)	$f_{yd} = f_{yk} / \gamma_s = 434.8 \text{ N/mm}^2$

Concrete cover to reinforcement

Nominal cover to top reinforcement	$c_{nom_t} = 30 \text{ mm}$
Nominal cover to bottom reinforcement	$c_{nom_b} = 40 \text{ mm}$
Fire resistance period to top of slab	$R_{top} = 30 \text{ min}$
Fire resistance period to bottom of slab	$R_{btm} = 30 \text{ min}$
Axis distance to top reinf (Table 5.8)	$a_{fi_t} = 10 \text{ mm}$
Axis distance to bottom reinf (Table 5.8)	$a_{fi_b} = 10 \text{ mm}$
Max bar diameter in top	$\phi_{max_t} = 10 \text{ mm}$
Max bar diameter in bottom	$\phi_{max_b} = 10 \text{ mm}$
Min. top cover requirement with regard to bond	$c_{min,b_t} = \phi_{max_t} = 10 \text{ mm}$
Min. btm cover requirement with regard to bond	$c_{min,b_b} = \phi_{max_b} = 10 \text{ mm}$
Reinforcement fabrication	Not subject to QA system
Cover allowance for deviation	$\Delta C_{dev} = 10 \text{ mm}$
Min. required nominal cover to top reinf	$c_{nom_t_min} = \max(a_{fi_t} - \phi_{max_t} / 2, c_{min,b_t} + \Delta C_{dev}) = 20.0 \text{ mm}$
Min. required nominal cover to bottom reinf	$c_{nom_b_min} = \max(a_{fi_b} - \phi_{max_b} / 2, c_{min,b_b} + \Delta C_{dev}) = 20.0 \text{ mm}$

PASS - There is sufficient cover to the top reinforcement
PASS - There is sufficient cover to the bottom reinforcement

Bending design checks

Redistribution ratio	$\delta = 1.0$
Limiting value of K	$K' = 0.598 \times \delta - 0.18 \times \delta^2 - 0.21 = 0.208$

Reinforcement design at midspan of span 1 (cl.6.1)

Length of span 1	$l_1 = 2700 \text{ mm}$
Design bending moment	$M_{p1} = 4.0 \text{ kNm/m}$
Reinforcement provided	A393 mesh
Area provided	$A_{sp1} = 393 \text{ mm}^2/\text{m}$
Effective depth to tension reinforcement	$d_{p1} = h - c_{nom_b} - \phi_{p1} / 2 = 105.0 \text{ mm}$
K factor	$K = M_{p1} / (b \times d_{p1}^2 \times f_{ck}) = 0.011$
	$K < K'$ - Compression reinforcement is not required
Lever arm	$z = \min(0.95 \times d_{p1}, d_{p1} / 2 \times (1 + \sqrt{1 - 3.53 \times K}))$ $z = 99.7 \text{ mm}$
Area of reinforcement required for bending	$A_{sp1_m} = M_{p1} / (f_{yd} \times z) = 92 \text{ mm}^2/\text{m}$
Minimum area required	$A_{sp1_min} = \max(0.26 \times (f_{ctm}/f_{yk}), 0.0013) \times b \times d_{p1} = 165 \text{ mm}^2/\text{m}$
Area of reinforcement required	$A_{sp1_req} = \max(A_{sp1_m}, A_{sp1_min}) = 165 \text{ mm}^2/\text{m}$

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PASS - Area of tension reinforcement provided is adequate (0.420)

Check reinforcement spacing

Reinforcement service stress

$$\sigma_s = (f_{yk} / \gamma_s) \times \min((A_{sp1_m}/A_{sp1}), 1.0) \times r_q = \mathbf{81.6 \text{ N/mm}^2}$$

Maximum allowable spacing (Table 7.3N)

$$s_{max_p1} = \mathbf{300 \text{ mm}}$$

Actual bar spacing

$$s_{p1} = \mathbf{200 \text{ mm}}$$

PASS - The reinforcement spacing is acceptable

Reinforcement design at midspan of span 2 (cl.6.1)

Length of span 2

$$l_2 = \mathbf{2700 \text{ mm}}$$

Design bending moment

$$M_{p2} = \mathbf{4.0 \text{ kNm/m}}$$

Reinforcement provided

$$\mathbf{A393 \text{ mesh}}$$

Area provided

$$A_{sp2} = \mathbf{393 \text{ mm}^2/\text{m}}$$

Effective depth to tension reinforcement

$$d_{p2} = h - c_{nom_b} - \phi_{p2} / 2 = \mathbf{105.0 \text{ mm}}$$

K factor

$$K = M_{p2} / (b \times d_{p2}^2 \times f_{ck}) = \mathbf{0.011}$$

K < K' - Compression reinforcement is not required

Lever arm

$$z = \min(0.95 \times d_{p2}, d_{p2} / 2 \times (1 + \sqrt{(1 - 3.53 \times K)}))$$

$$z = \mathbf{99.7 \text{ mm}}$$

Area of reinforcement required for bending

$$A_{sp2_m} = M_{p2} / (f_{yd} \times z) = \mathbf{92 \text{ mm}^2/\text{m}}$$

Minimum area required

$$A_{sp2_min} = \max(0.26 \times (f_{ctm}/f_{yk}), 0.0013) \times b \times d_{p2} = \mathbf{165 \text{ mm}^2/\text{m}}$$

Area of reinforcement required

$$A_{sp2_req} = \max(A_{sp2_m}, A_{sp2_min}) = \mathbf{165 \text{ mm}^2/\text{m}}$$

PASS - Area of tension reinforcement provided is adequate (0.420)

Check reinforcement spacing

Reinforcement service stress

$$\sigma_s = (f_{yk} / \gamma_s) \times \min((A_{sp2_m}/A_{sp2}), 1.0) \times r_q = \mathbf{81.6 \text{ N/mm}^2}$$

Maximum allowable spacing (Table 7.3N)

$$s_{max_p2} = \mathbf{300 \text{ mm}}$$

Actual bar spacing

$$s_{p2} = \mathbf{200 \text{ mm}}$$

PASS - The reinforcement spacing is acceptable

Reinforcement design at midspan of span 3 (cl.6.1)

Length of span 3

$$l_3 = \mathbf{2700 \text{ mm}}$$

Design bending moment

$$M_{p3} = \mathbf{8.0 \text{ kNm/m}}$$

Reinforcement provided

$$\mathbf{A393 \text{ mesh}}$$

Area provided

$$A_{sp3} = \mathbf{393 \text{ mm}^2/\text{m}}$$

Effective depth to tension reinforcement

$$d_{p3} = h - c_{nom_b} - \phi_{p3} / 2 = \mathbf{105.0 \text{ mm}}$$

K factor

$$K = M_{p3} / (b \times d_{p3}^2 \times f_{ck}) = \mathbf{0.023}$$

K < K' - Compression reinforcement is not required

Lever arm

$$z = \min(0.95 \times d_{p3}, d_{p3} / 2 \times (1 + \sqrt{(1 - 3.53 \times K)}))$$

$$z = \mathbf{99.7 \text{ mm}}$$

Area of reinforcement required for bending

$$A_{sp3_m} = M_{p3} / (f_{yd} \times z) = \mathbf{184 \text{ mm}^2/\text{m}}$$

Minimum area required

$$A_{sp3_min} = \max(0.26 \times (f_{ctm}/f_{yk}), 0.0013) \times b \times d_{p3} = \mathbf{165 \text{ mm}^2/\text{m}}$$

Area of reinforcement required

$$A_{sp3_req} = \max(A_{sp3_m}, A_{sp3_min}) = \mathbf{184 \text{ mm}^2/\text{m}}$$

PASS - Area of tension reinforcement provided is adequate (0.469)

Check reinforcement spacing

Reinforcement service stress

$$\sigma_s = (f_{yk} / \gamma_s) \times \min((A_{sp3_m}/A_{sp3}), 1.0) \times r_q = \mathbf{163.3 \text{ N/mm}^2}$$

Maximum allowable spacing (Table 7.3N)

$$s_{max_p3} = \mathbf{296 \text{ mm}}$$

Actual bar spacing

$$s_{p3} = \mathbf{200 \text{ mm}}$$

PASS - The reinforcement spacing is acceptable

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Reinforcement design at support 1 (cl.6.1)

Design bending moment

$$M_{n1} = 11.0 \text{ kNm/m}$$

Reinforcement provided

A393 mesh

Area provided

$$A_{sn1} = 393 \text{ mm}^2/\text{m}$$

Effective depth to tension reinforcement

$$d_{n1} = h - c_{nom_t} - \phi_{n1} / 2 = 115.0 \text{ mm}$$

K factor

$$K = M_{n1} / (b \times d_{n1}^2 \times f_{ck}) = 0.026$$

K < K' - Compression reinforcement is not required

Lever arm

$$z = \min(0.95 \times d_{n1}, d_{n1} / 2 \times (1 + \sqrt{(1 - 3.53 \times K)}))$$

$$z = 109.2 \text{ mm}$$

Area of reinforcement required for bending

$$A_{sn1_m} = M_{n1} / (f_{yd} \times z) = 232 \text{ mm}^2/\text{m}$$

Minimum area required

$$A_{sn1_min} = \max(0.26 \times (f_{ctm}/f_{yk}), 0.0013) \times b \times d_{n1} = 181 \text{ mm}^2/\text{m}$$

Area of reinforcement required

$$A_{sn1_req} = \max(A_{sn1_m}, A_{sn1_min}) = 232 \text{ mm}^2/\text{m}$$

PASS - Area of tension reinforcement provided is adequate (0.589)

Check reinforcement spacing

Reinforcement service stress

$$\sigma_s = (f_{yk} / \gamma_s) \times \min((A_{sn1_m}/A_{sn1}), 1.0) \times r_q = 205.0 \text{ N/mm}^2$$

Maximum allowable spacing (Table 7.3N)

$$s_{max_n1} = 244 \text{ mm}$$

Actual bar spacing

$$s_{n1} = 200 \text{ mm}$$

PASS - The reinforcement spacing is acceptable

Reinforcement design at support 2 (cl.6.1)

Design bending moment

$$M_{n2} = 8.0 \text{ kNm/m}$$

Reinforcement provided

A393 mesh

Area provided

$$A_{sn2} = 393 \text{ mm}^2/\text{m}$$

Effective depth to tension reinforcement

$$d_{n2} = h - c_{nom_t} - \phi_{n2} / 2 = 115.0 \text{ mm}$$

K factor

$$K = M_{n2} / (b \times d_{n2}^2 \times f_{ck}) = 0.019$$

K < K' - Compression reinforcement is not required

Lever arm

$$z = \min(0.95 \times d_{n2}, d_{n2} / 2 \times (1 + \sqrt{(1 - 3.53 \times K)}))$$

$$z = 109.2 \text{ mm}$$

Area of reinforcement required for bending

$$A_{sn2_m} = M_{n2} / (f_{yd} \times z) = 168 \text{ mm}^2/\text{m}$$

Minimum area required

$$A_{sn2_min} = \max(0.26 \times (f_{ctm}/f_{yk}), 0.0013) \times b \times d_{n2} = 181 \text{ mm}^2/\text{m}$$

Area of reinforcement required

$$A_{sn2_req} = \max(A_{sn2_m}, A_{sn2_min}) = 181 \text{ mm}^2/\text{m}$$

PASS - Area of tension reinforcement provided is adequate (0.460)

Check reinforcement spacing

Reinforcement service stress

$$\sigma_s = (f_{yk} / \gamma_s) \times \min((A_{sn2_m}/A_{sn2}), 1.0) \times r_q = 149.1 \text{ N/mm}^2$$

Maximum allowable spacing (Table 7.3N)

$$s_{max_n2} = 300 \text{ mm}$$

Actual bar spacing

$$s_{n2} = 200 \text{ mm}$$

PASS - The reinforcement spacing is acceptable

Reinforcement design at support 3 (cl.6.1)

Design bending moment

$$M_{n3} = 12.0 \text{ kNm/m}$$

Reinforcement provided

A393 mesh

Area provided

$$A_{sn3} = 393 \text{ mm}^2/\text{m}$$

Effective depth to tension reinforcement

$$d_{n3} = h - c_{nom_t} - \phi_{n3} / 2 = 115.0 \text{ mm}$$

K factor

$$K = M_{n3} / (b \times d_{n3}^2 \times f_{ck}) = 0.028$$

K < K' - Compression reinforcement is not required

Lever arm

$$z = \min(0.95 \times d_{n3}, d_{n3} / 2 \times (1 + \sqrt{(1 - 3.53 \times K)}))$$

$$z = 109.2 \text{ mm}$$

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Area of reinforcement required for bending

$$A_{sn3_m} = M_{n3} / (f_{yd} \times z) = \mathbf{253 \text{ mm}^2/m}$$

Minimum area required

$$A_{sn3_min} = \max(0.26 \times (f_{ctm}/f_{yk}), 0.0013) \times b \times d_{n3} = \mathbf{181 \text{ mm}^2/m}$$

Area of reinforcement required

$$A_{sn3_req} = \max(A_{sn3_m}, A_{sn3_min}) = \mathbf{253 \text{ mm}^2/m}$$

PASS - Area of tension reinforcement provided is adequate (0.643)

Check reinforcement spacing

Reinforcement service stress

$$\sigma_s = (f_{yk} / \gamma_s) \times \min((A_{sn3_m}/A_{sn3}), 1.0) \times r_q = \mathbf{223.6 \text{ N/mm}^2}$$

Maximum allowable spacing (Table 7.3N)

$$s_{max_n3} = \mathbf{221 \text{ mm}}$$

Actual bar spacing

$$s_{n3} = \mathbf{200 \text{ mm}}$$

PASS - The reinforcement spacing is acceptable

Shear design checks

Shear resistance constant (cl. 6.2.2)

$$C_{Rd,c} = 0.18 \text{ N/mm}^2 / \gamma_c = \mathbf{0.12 \text{ N/mm}^2}$$

Shear capacity check at support 1

Shear force

$$V_1 = \mathbf{45.0 \text{ kN/m}}$$

Effective depth factor (cl. 6.2.2)

$$k = \min(2.0, 1 + (200 \text{ mm} / d_{n1})^{0.5}) = \mathbf{2.000}$$

Reinforcement ratio

$$\rho_l = \min(0.02, A_{sn1} / (b \times d_{n1})) = \mathbf{0.0034}$$

Minimum shear resistance (Exp. 6.3N)

$$V_{Rd,c_min} = 0.035 \text{ N/mm}^2 \times k^{1.5} \times (f_{ck} / 1 \text{ N/mm}^2)^{0.5} \times b \times d_{n1}$$

$$V_{Rd,c_min} = \mathbf{64.4 \text{ kN/m}}$$

Shear resistance (Exp. 6.2a)

$$V_{Rd,c1} = \max(V_{Rd,c_min}, C_{Rd,c} \times k \times (100 \times \rho_l \times (f_{ck}/1 \text{ N/mm}^2))^{0.333} \times b \times d_{n1})$$

$$V_{Rd,c1} = \mathbf{64.4 \text{ kN/m}}$$

PASS - Shear capacity is adequate (0.699)

Shear capacity check at support 2

Shear force

$$V_2 = \mathbf{40.0 \text{ kN/m}}$$

Effective depth factor (cl. 6.2.2)

$$k = \min(2.0, 1 + (200 \text{ mm} / d_{n2})^{0.5}) = \mathbf{2.000}$$

Reinforcement ratio

$$\rho_l = \min(0.02, A_{sn2} / (b \times d_{n2})) = \mathbf{0.0034}$$

Minimum shear resistance (Exp. 6.3N)

$$V_{Rd,c_min} = 0.035 \text{ N/mm}^2 \times k^{1.5} \times (f_{ck} / 1 \text{ N/mm}^2)^{0.5} \times b \times d_{n2}$$

$$V_{Rd,c_min} = \mathbf{64.4 \text{ kN/m}}$$

Shear resistance (Exp. 6.2a)

$$V_{Rd,c2} = \max(V_{Rd,c_min}, C_{Rd,c} \times k \times (100 \times \rho_l \times (f_{ck}/1 \text{ N/mm}^2))^{0.333} \times b \times d_{n2})$$

$$V_{Rd,c2} = \mathbf{64.4 \text{ kN/m}}$$

PASS - Shear capacity is adequate (0.621)

Shear capacity check at support 3

Shear force

$$V_3 = \mathbf{45.0 \text{ kN/m}}$$

Effective depth factor (cl. 6.2.2)

$$k = \min(2.0, 1 + (200 \text{ mm} / d_{n3})^{0.5}) = \mathbf{2.000}$$

Reinforcement ratio

$$\rho_l = \min(0.02, A_{sn3} / (b \times d_{n3})) = \mathbf{0.0034}$$

Minimum shear resistance (Exp. 6.3N)

$$V_{Rd,c_min} = 0.035 \text{ N/mm}^2 \times k^{1.5} \times (f_{ck} / 1 \text{ N/mm}^2)^{0.5} \times b \times d_{n3}$$

$$V_{Rd,c_min} = \mathbf{64.4 \text{ kN/m}}$$

Shear resistance (Exp. 6.2a)

$$V_{Rd,c3} = \max(V_{Rd,c_min}, C_{Rd,c} \times k \times (100 \times \rho_l \times (f_{ck}/1 \text{ N/mm}^2))^{0.333} \times b \times d_{n3})$$

$$V_{Rd,c3} = \mathbf{64.4 \text{ kN/m}}$$

PASS - Shear capacity is adequate (0.699)

Shear capacity check at support 4

Shear force

$$V_4 = \mathbf{15.0 \text{ kN/m}}$$

Reinforcement provided

$$\mathbf{A393 \text{ mesh}}$$

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Area provided $A_{sd4} = 393 \text{ mm}^2/\text{m}$
Effective depth $d_{d4} = h - c_{nom_b} - \phi_{d4} / 2 = 105.0 \text{ mm}$
Effective depth factor (cl. 6.2.2) $k = \min(2.0, 1 + (200 \text{ mm} / d_{d4})^{0.5}) = 2.000$
Reinforcement ratio $\rho_l = \min(0.02, A_{sd4} / (b \times d_{d4})) = 0.0037$
Minimum shear resistance (Exp. 6.3N) $V_{Rd,c_min} = 0.035 \text{ N/mm}^2 \times k^{1.5} \times (f_{ck} / 1 \text{ N/mm}^2)^{0.5} \times b \times d_{d4}$
 $V_{Rd,c_min} = 58.8 \text{ kN/m}$
Shear resistance (Exp. 6.2a) $V_{Rd,c4} = \max(V_{Rd,c_min}, C_{Rd,c} \times k \times (100 \times \rho_l \times (f_{ck} / 1 \text{ N/mm}^2))^{0.333} \times b \times d_{d4})$
 $V_{Rd,c4} = 58.8 \text{ kN/m}$

PASS - Shear capacity is adequate (0.255)

Deflection checks

Basic span-to-depth ratio deflection check span 1 (cl. 7.4.2)

Reference reinforcement ratio $\rho_0 = (f_{ck} / 1 \text{ N/mm}^2)^{0.5} / 1000 = 0.0057$
Required tension reinforcement ratio $\rho = \max(0.0035, A_{sp1_m} / (b \times d_{p1})) = 0.0035$
Required compression reinforcement ratio $\rho' = A_{scp1_req} / (b \times d_{p1}) = 0.0000$
Structural system factor (Table 7.4N) $K_\delta = 1.3$
Basic span-to-depth ratio limit $ratio_{lim1_bas} = K_\delta \times [11 + 1.5 \times (f_{ck} / 1 \text{ N/mm}^2)^{0.5} \times \rho_0 / \rho + 3.2 \times (f_{ck} / 1 \text{ N/mm}^2)^{0.5} \times (\rho_0 / \rho - 1)^{1.5}]$
(Exp. 7.16a) $ratio_{lim1_bas} = 43.51$
Modified span-to-depth ratio limit
 $ratio_{lim1} = \min(40 \times K_\delta, \min(1.5, (500 \text{ N/mm}^2 / f_{yk}) \times (A_{sp1} / A_{sp1_m})) \times ratio_{lim1_bas}) = 52.00$

Actual span-to-depth ratio $ratio_{act1} = l_1 / d_{p1} = 25.71$

PASS - Span-to-depth ratio is acceptable (0.495)

Basic span-to-depth ratio deflection check span 2 (cl. 7.4.2)

Reference reinforcement ratio $\rho_0 = (f_{ck} / 1 \text{ N/mm}^2)^{0.5} / 1000 = 0.0057$
Required tension reinforcement ratio $\rho = \max(0.0035, A_{sp2_m} / (b \times d_{p2})) = 0.0035$
Required compression reinforcement ratio $\rho' = A_{scp2_req} / (b \times d_{p2}) = 0.0000$
Structural system factor (Table 7.4N) $K_\delta = 1.5$
Basic span-to-depth ratio limit $ratio_{lim2_bas} = K_\delta \times [11 + 1.5 \times (f_{ck} / 1 \text{ N/mm}^2)^{0.5} \times \rho_0 / \rho + 3.2 \times (f_{ck} / 1 \text{ N/mm}^2)^{0.5} \times (\rho_0 / \rho - 1)^{1.5}]$
(Exp. 7.16a) $ratio_{lim2_bas} = 50.21$
Modified span-to-depth ratio limit
 $ratio_{lim2} = \min(40 \times K_\delta, \min(1.5, (500 \text{ N/mm}^2 / f_{yk}) \times (A_{sp2} / A_{sp2_m})) \times ratio_{lim2_bas}) = 60.00$

Actual span-to-depth ratio $ratio_{act2} = l_2 / d_{p2} = 25.71$

PASS - Span-to-depth ratio is acceptable (0.429)

Basic span-to-depth ratio deflection check span 3 (cl. 7.4.2)

Reference reinforcement ratio $\rho_0 = (f_{ck} / 1 \text{ N/mm}^2)^{0.5} / 1000 = 0.0057$
Required tension reinforcement ratio $\rho = \max(0.0035, A_{sp3_m} / (b \times d_{p3})) = 0.0035$
Required compression reinforcement ratio $\rho' = A_{scp3_req} / (b \times d_{p3}) = 0.0000$
Structural system factor (Table 7.4N) $K_\delta = 1.3$
Basic span-to-depth ratio limit $ratio_{lim3_bas} = K_\delta \times [11 + 1.5 \times (f_{ck} / 1 \text{ N/mm}^2)^{0.5} \times \rho_0 / \rho + 3.2 \times (f_{ck} / 1 \text{ N/mm}^2)^{0.5} \times (\rho_0 / \rho - 1)^{1.5}]$
(Exp. 7.16a) $ratio_{lim3_bas} = 43.51$
Modified span-to-depth ratio limit
 $ratio_{lim3} = \min(40 \times K_\delta, \min(1.5, (500 \text{ N/mm}^2 / f_{yk}) \times (A_{sp3} / A_{sp3_m})) \times ratio_{lim3_bas}) = 52.00$

Actual span-to-depth ratio $ratio_{act3} = l_3 / d_{p3} = 25.71$

PASS - Span-to-depth ratio is acceptable (0.495)

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Reinforcement sketch

The following sketch is indicative only. Note that additional reinforcement may be required in accordance with clauses 9.2.1.2, 9.2.1.4 and 9.2.1.5 of EN 1992-1-1:2004 to meet detailing rules.

