

Design and Construction of Cantilevered Reinforced Concrete Structures

The structural stability of cantilevered reinforced concrete structures in particular those of pure slab type relies on their proper design, construction and maintenance. Furthermore, the fact that weathering may lead to the early degradation of material strength should be borne in mind when carrying out the design and construction of cantilevered members exposed to weathering^[1]. Common examples of this type of structural elements are projecting structures located on the exteriors of buildings like canopies, balconies, bay windows, A/C hoods, A/C platforms, flowerbeds etc. Their collapse would have serious consequences.

2. This Practice Note gives guidance to Authorized Persons and Registered Structural Engineers on the safe design and construction of cantilevered reinforced concrete structures. Appendix A gives guidelines on structural design, construction, drainage provision and site supervision for achieving the necessary safety standards. Appendix B and Appendix C provide recommended details for the arrangement of reinforcements for cantilevered slabs and beams respectively. Structural submissions conforming to these recommendations will be considered as complying with the performance requirements set out in Building (Construction) Regulation 4. The requirements on supervision, standards of workmanship and submission of construction reports will be the Building Authority's conditions for approval of plans and consent to commence works.



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Building Authority

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Cantilevered Reinforced Concrete Structures

^[1] For the purpose of this practice note, cantilevered structures under permanent solid cover located at not greater than one storey height and of at least the same plan area as the structure may be considered as not exposed to weathering.

Guidance Notes on Design and Construction of Cantilevered Reinforced Concrete Structures

General Requirements

1. The structural design of cantilevered structures should satisfy the following requirements:-
 - (a) For cantilever span more than 1000 mm, a beam-and-slab type of arrangement should be used instead of pure slab cantilever where practicable.
 - (b) The span to overall depth of cantilevered beams or slabs should not be greater than 7 and the members should be of adequate size to satisfy both the structural strength and durability requirements.
 - (c) Superimposed loads due to finishes, parapets and waterproofing materials, and loads due to maintenance work and possible ponding resulting from malfunctioning of the drainage system should be accurately assessed and allowed for in the design.
 - (d) Cantilevered structures, especially those projecting over streets, should be detailed in such a manner that they may be demolished or replaced without affecting the safety and integrity of the main structure of the building.

2. The construction of cantilevered structures should satisfy the following requirements:-
 - (a) All cantilevered structures should be cast monolithically with and at the same time as the directly supporting members. Construction joints should **not** be located along the external edge of the supporting members. In case this is unavoidable, any alternative construction method must be submitted for prior approval. Such method should ensure that the finished product would be able to attain a structural strength no less than that provided by monolithic construction, and that it would not invite ingress of water through the joint.
 - (b) Adequate bar spacers should be provided to maintain the position and alignment of the steel reinforcement.
 - (c) During concreting, adequate compaction should be given to ensure good quality concrete. Every endeavour should also be made to avoid steel reinforcement from being displaced or depressed.
 - (d) All props to the soffit of formwork for cantilevered structures should be maintained for at least 14 days after concreting.

3. The AP/RSE should provide the appropriate level of supervision and inspection on the construction of cantilevered structures so as to ensure compliance with

the approved plans.

4. Means to prevent accumulation of water should be provided to cantilevered structures exposed to weathering.^[1] In this connection the following are to be observed:-
- (a) Effective waterproofing should be provided.
 - (b) A fall of not less than 1:75 should be laid. Wherever practicable, adequate drainage should be provided to drain the water away from the cantilevered structure. If for any reason, the water is designed to just cascade down from the edge of the cantilevered structure, the AP/RSE should first make sure that by so doing it will not create any nuisance to anyone in accordance with Building (Planning) Regulation 4(b). A continuous drip or groove should always be provided at the bottom edge of the cantilevered structure to keep the dripping water away.
 - (c) Where the cantilevered structure is not accessible for cleaning/maintenance, the maximum distance between the drainage outlets, if provided, should be not more than 5 m.
 - (d) Every endeavour should be made to avoid penetration or embedment of pipes in cantilevered structures, especially slab elements. If unavoidable, consideration must be given to any local reduction in structural strength affected by the surface drainage system or embedded service pipes and ducts. In this regard, you are reminded to make reference to PNAP 230 on the requirements and guidelines of embedment of water-borne pipes inside reinforced concrete beams and slabs.

Cantilevered Beams

5. The structural design of cantilevered beams should satisfy the following requirements:-
- (a) The overall depth at support should be at least 300mm.
 - (b) Top and bottom reinforcement should be securely held in position by stirrups with the top bars extended a minimum length of 45 times the bar diameter of the steel bar into the supporting columns, walls or the penultimate span of continuous beams or slabs if practical. Where support by cross beam cannot be avoided, the supporting beam and the adjacent internal slabs should be adequately designed and properly detailed for any internal moment, torsion, shear and axial force so induced.
 - (c) For cantilevered beams exposed to weathering^[1], the minimum cover to all reinforcement should not be less than 40mm.

^[1] For the purpose of this practice note, cantilevered structures under permanent solid cover located at not greater than one storey height and of at least the same plan area as the structure may be considered as not exposed to weathering.

Cantilevered Slabs

6. The structural design of cantilevered slabs should satisfy the following requirements:-
 - (a) The minimum overall thickness should be--
 - (i) 100 mm for span not greater than 500 mm;
 - (ii) 125 mm for span greater than 500 mm but not greater than 750 mm;
 - (iii) 150 mm for span greater than 750 mm.
 - (b) Any wall supporting the cantilever slab, except that for very small span slabs like air-conditioner hoods, should be of sufficient thickness to provide the necessary rigidity. This is in addition to any other design consideration that is required for the wall itself.
 - (c) Cantilevered slabs should be reinforced with high yield steel bars in both faces and in both directions. Main reinforcement bars should be at least 10mm diameter and spacing should not be greater than 150 mm, and the steel area should not be less than 0.25% of the cross-sectional area of the structural concrete.
 - (d) The main reinforcement of cantilevered slabs should have a minimum anchorage length of 45 times the bar diameter of the steel bar and should be rigidly fixed to the reinforcement of the supporting members. For cantilevered slabs with drop at the supporting end, top main reinforcement bars of not greater than 16 mm in diameter should be used in order that an effective and proper anchorage into the supporting beams and internal slab can be developed. Reinforcement details should be drawn in a sufficiently large scale to indicate clearly the connections.
 - (e) Consideration and specific details should be provided for--
 - (i) cantilevered slabs continuing around corners of buildings due to increase in slab area and a change in direction of the main bars;
 - (ii) the side edge of cantilevered slabs where there is an additional load from return parapets running parallel to the cantilever span direction.
7. The requirements set out in paragraph 6 above do not apply to in-fill slabs enclosed by edge beams, or slabs supported in such a way that they do not behave similar to cantilevered slabs.
8. Cantilevered slabs exposed to weathering^[1] should satisfy the following additional requirements:-
 - (a) The maximum crack width at the tension face should be limited to 0.1 mm when carrying out design check under the serviceability limit state or the stress of deformed high yield steel reinforcement used should not exceed 100 N/mm² when checking the flexural tension under the

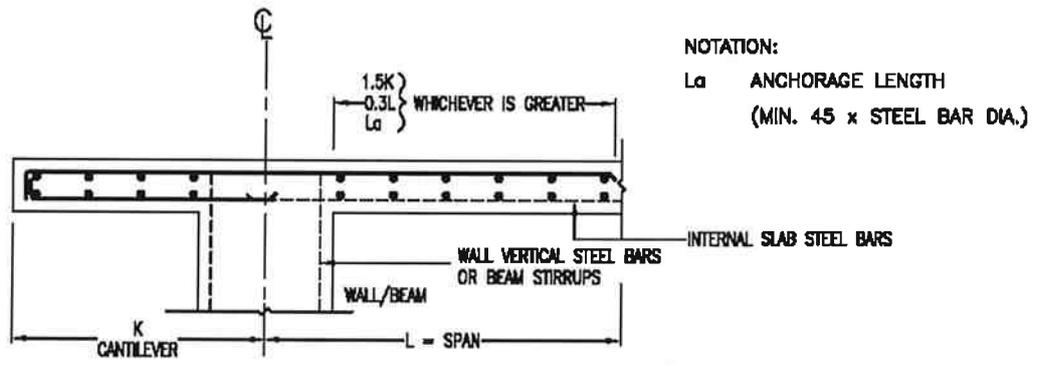
working load condition. The minimum cover to all reinforcement at the exposed surface side of the slab should not be less than 40mm.

- (b) In addition, for cantilevered slabs with a span exceeding 750 mm, the AP/RSE, in conjunction with the registered general building contractor where appropriate, is required to submit a construction report upon completion of the works. A Form BA 14 confirming that the works have been carried out in accordance with the approved plans and are structurally safe should also be submitted.

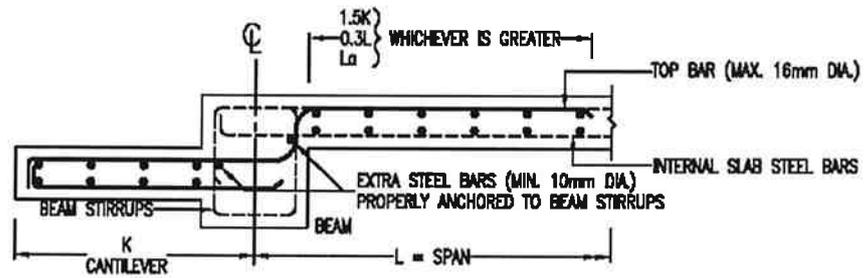
9. The construction report required under paragraph 8(b) should include the following: -

- (a) an as-built plan showing --
 - (i) the location and dimensions of the members of the cantilevered slab;
 - (ii) the direction and gradient of the fall, where applicable;
 - (iii) the location of the drainage outlets, where applicable;
 - (iv) the thickness of screeding and finishes;
 - (v) the location and details of any construction joints;
 - (vi) the grade of concrete and steel reinforcement;
 - (vii) the diameter and spacing of steel reinforcement in the cantilevered slab;
 - (viii) the date on which the concrete was cast; and
 - (ix) the concrete cover of the steel reinforcement at critical positions, as measured by covermeter.
- (b) record photographs of the cantilevered slab and its supporting members showing --
 - (i) the condition and arrangement of the in-position steel reinforcement prior to concreting; and
 - (ii) the condition after concreting but before laying of the finishes and waterproofing materials.

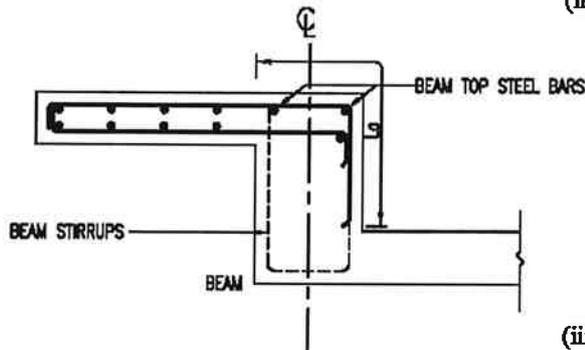
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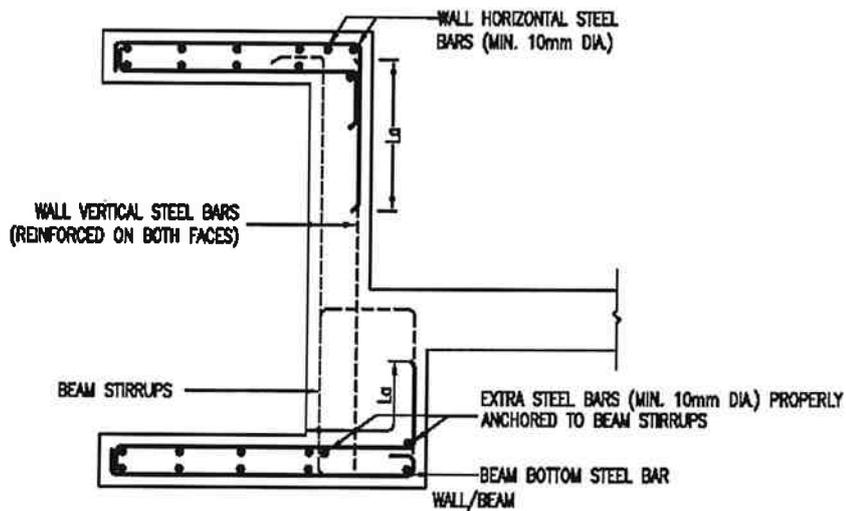
(i) CONTINUOUS SLAB



(ii) DROP SLAB

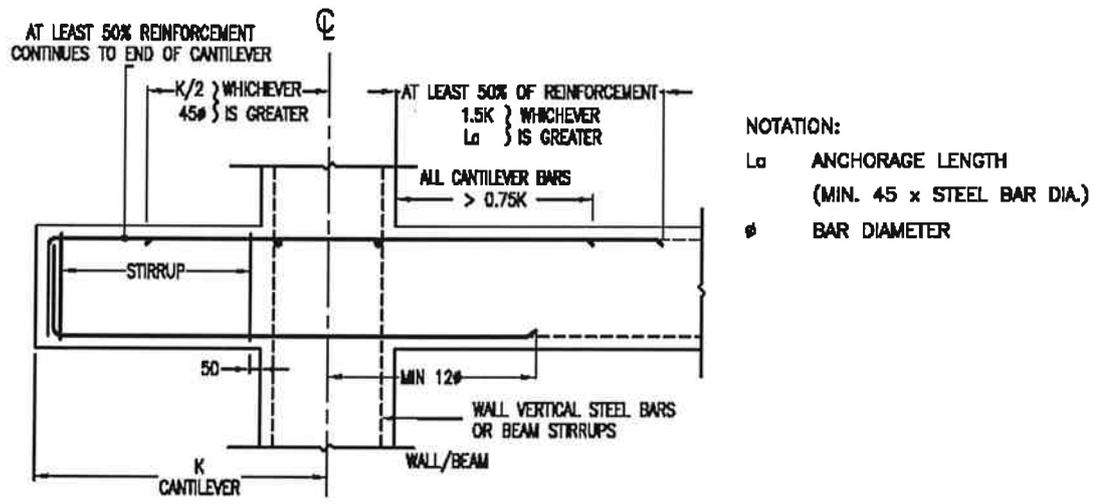


(iii) SUPPORTED AT BEAM TOP

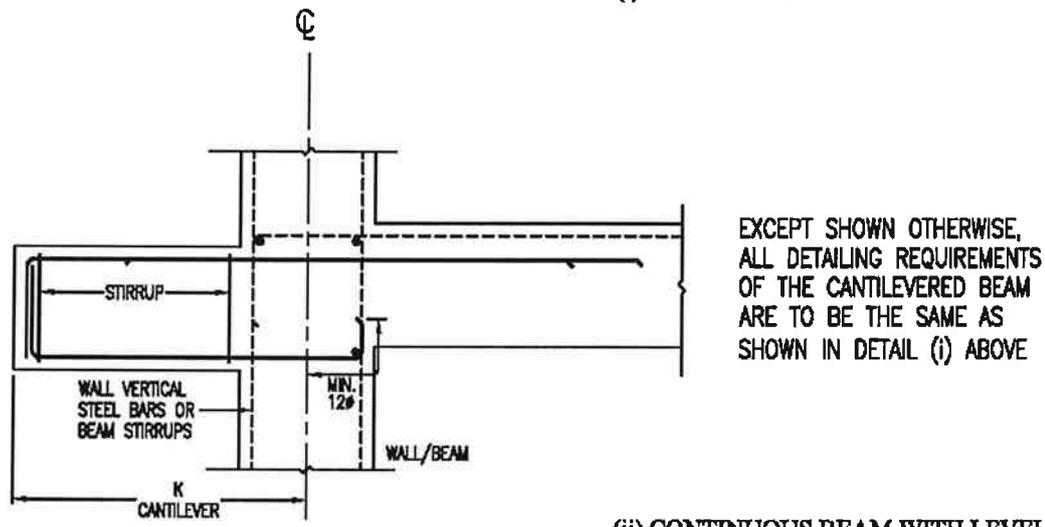


(iv) SUPPORTED AT WALL & BEAM SOFFIT

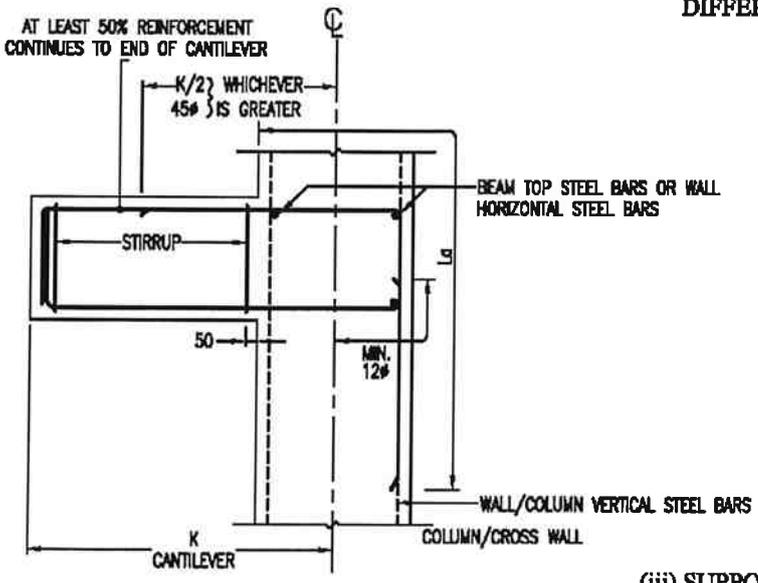
**TYPICAL DETAILS SHOWING THE ARRANGEMENT OF REINFORCEMENT
IN CANTILEVERED SLABS PROJECTED FROM DIFFERENT TYPES OF SUPPORT**



(i) CONTINUOUS BEAM

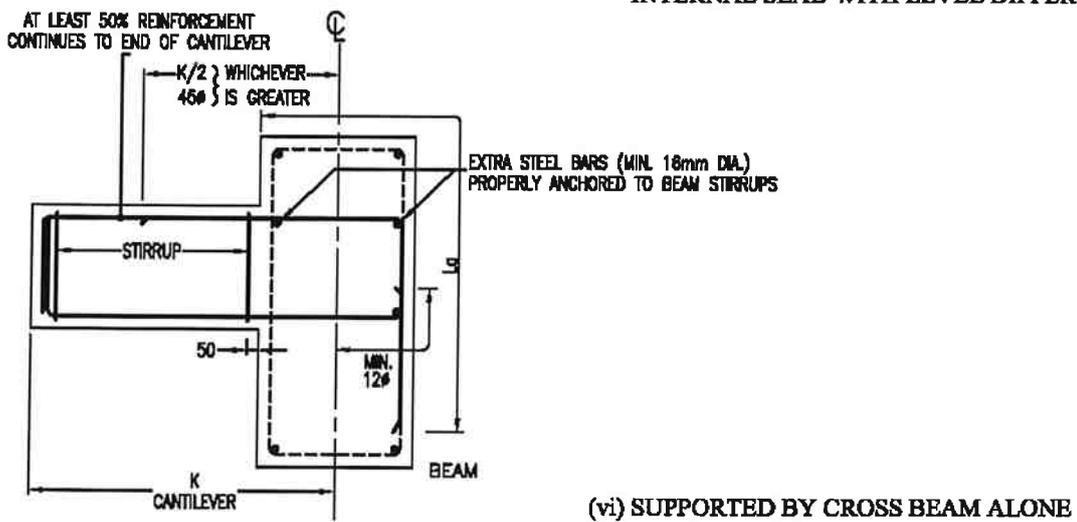
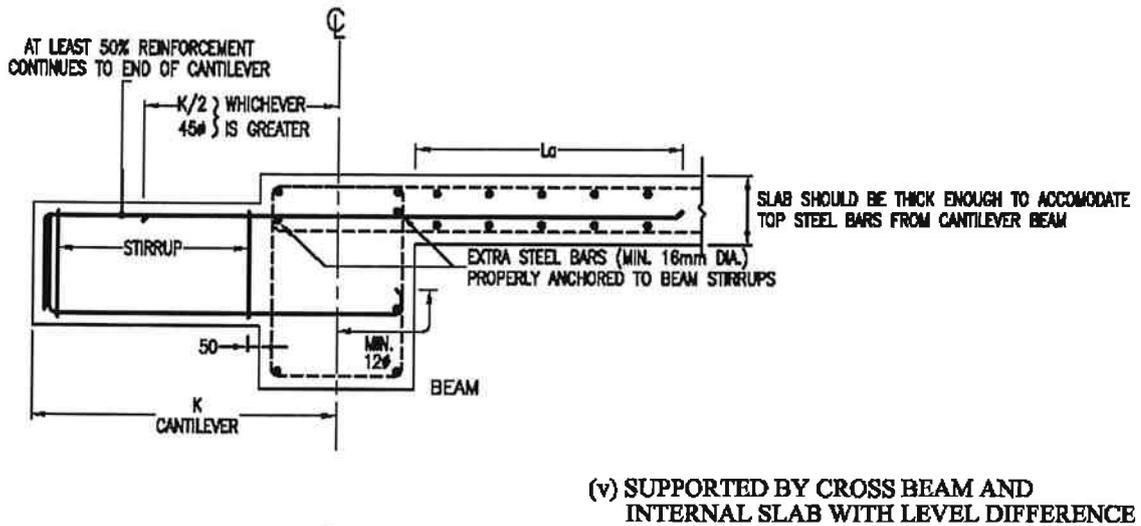
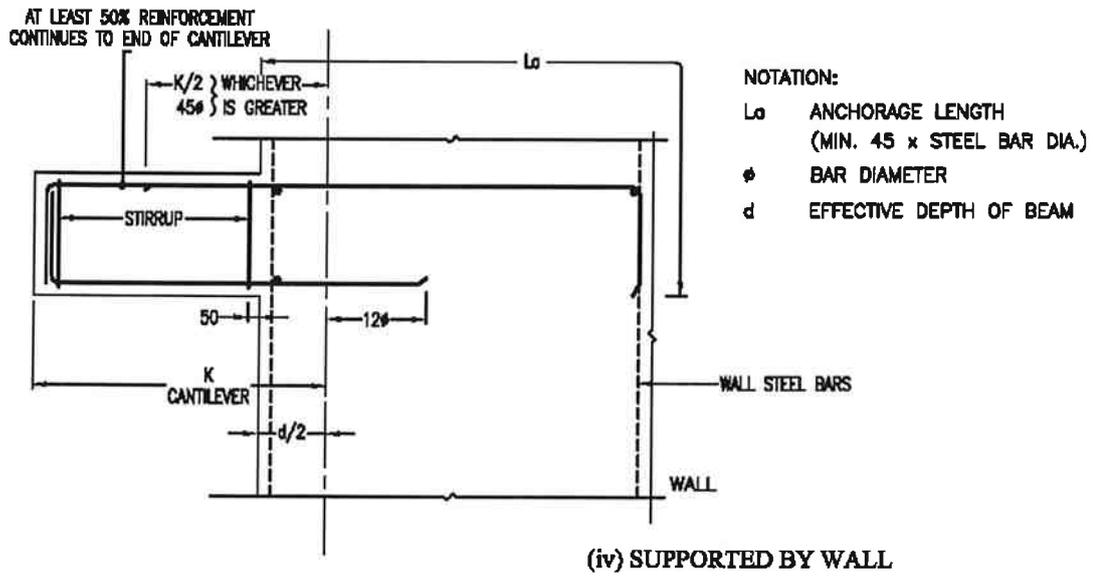


(ii) CONTINUOUS BEAM WITH LEVEL DIFFERENCE



(iii) SUPPORTED BY COLUMN/CROSS WALL

TYPICAL DETAILS SHOWING THE ARRANGEMENT OF REINFORCEMENT IN CANTILEVERED BEAMS PROJECTED FROM DIFFERENT TYPES OF SUPPORT



**TYPICAL DETAILS SHOWING THE ARRANGEMENT OF REINFORCEMENT
IN CANTILEVERED BEAMS PROJECTED FROM DIFFERENT TYPES OF SUPPORT**