Tanta University **Faculty of Engineering**

SHALLOW TO DEEP BEAM TRANSITION FOR HIGH STRENGTH CONCRETE

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ABSTRACT

Shear behavior of high strength concrete differs from that of normal strength concrete. Mortar strength of the former is much stronger and the onset of failure might occur in the coarse aggregates or at the interface. In most of the international codes there is no unified limit for the shallow to beam transition of beams made of high strength concrete. Since their behavior and design concepts are different, determining both flexure and shear reinforcement are dissimilar in quantity and detailing. Therefore, it is important to select a suitable beam classification before conducting design procedures. In addition, a discrepancy among international codes exists for normal concrete strength beams classification. The overall work scheme of the present study is divided into three phases containing experimental program for 16 specimens, numerical analysis for more than 120 beams and also analytical work. Phase I aims at identifying experimentally and numerically the transition from shallow to deep beam behavior of both continuous and simple beams made of high and normal strength concrete. Phase II is devoted to inspect the impact of beam classification on reinforcement detailing and the associated behavior for high strength concrete for simply supported and continuous beams. The experimental and numerical investigations focused on the anticipated mode of failure, load-deflection characteristics, strain distribution, crack width to address the mechanism of load transfer and the appropriate modeling methodology.

A new analytical unified design for both shallow and deep beams is proposed in Phase III. The methodology is adopted to account for both beam and arch actions exhibited in behavior through proper weighting functions.

In addition, simple design aids in form of charts and tables are introduced for the flexural design. Beam analogy and Strut-and-Tie model are utilized in the suggested procedure for the ultimate and serviceability limit states. This research suggested a consistent definition for the transition limit from shallow to deep beam behavior with various continuity conditions for ordinary and high strength concrete members. Also, the proposed design procedure was proved to be in good agreement with the experimental and numerical analysis.

SUMMARY

A discrepancy exists among most of the international codes for limit of the shallow to deep beam transition of members made of high strength concrete. The mechanism of mobilizing internal resistance of the section to the applied actions usually includes mortar-aggregate interlocking in ordinary strength concrete. Modes of failure in high strength concrete may be different depending on the matrix structure and the aggregates texture besides particle strength and interface characteristics. Combined stresses in continuous beams in the vicinity of interior supports which may have different behavior from simply supported beams. In addition, shear resistance in deep members may require provision of horizontal skin reinforcement along with vertical stirrups. Distribution of main longitudinal reinforcement along part of the beam height as required by particular codes for deep members may lead to response different from members with concentrated alignment of reinforcement. All of these salient features influence the load path within the members, the cracking pattern and the failure mode. In turn, mobilization of beam action and arch action components will be affected as such with added sophistication of the problem. Therefore, it is prudent to carry out experimental, numerical and analytical investigations to study the behavior with these respects and to propose a unified design procedure suitable for incorporation with rational provisions.

The overall work scheme of the present study is divided into three phases containing experimental program for 16 beams, numerical analysis for more than 120 beams and analytical work for a lot numbers of shallow

and deep beams. The first phase (I) provides an attempt for identifying experimentally and numerically the transition from shallow to deep beam behavior of both continuous and simple beams made of high and normal strength concrete. While the second phase (II) is directed towards inspecting the impact of beam classification of simple and continuous beams on detailing and behavior for high strength concrete. Each phase is divided into experimental and numerical investigations. The final target of this research, phase (III), is proposing a new analytical unified design for both shallow and deep beams. In addition, using beam idealization and strut-and-tie model helped to provide simple design aids in form of charts and tables for the flexural procedure of the proposed method.

In the experimental investigation of the first phase, twelve high strength reinforced concrete beams were tested to failure. The specimens were divided into three groups. The first group consisted of six high strength reinforced concrete two-span continuous beams and the second one has four high strength reinforced concrete simple beams. Test specimens of each group had the same length, width, ratio of main bottom and top longitudinal reinforcement and ratio of vertical and horizontal reinforcement. The third group included two simple beams loaded by two point loads with L_n/t of 5.8 and shear span–to–depth ratio a/d of 1.25. The beams had different flexure reinforcement ratios equal to $0.18\,\mu_{blanced}$ and $0.62\,\mu_{blanced}$. The main parameters of tested beams were the span/depth ratios, l/d, in the range between 2.23 & 6.1 for continuous beams and 3.1 and 6.6 for simple beams. The experimental results were compared with the predictions of the nonlinear 3-D finite element analysis using ANSYS 5.4® and a comprehensive parametric study for different concrete strength was made.

In the experimental investigation of the second phase, four high strength reinforced concrete beams were tested to failure. The specimens were divided into two groups. For each group, the dimensions of specimens were kept unchanged. The first group comprised two continuous beams of clear span–to–total depth L_n/t equal 2.68 having different main steel arrangement. The second group consisted of two simple beams of L_n/t equal 2.16 have different design type. In the numerical part of this phase, a comprehensive parametric study with nonlinear finite element analysis using ANSYS 5.4 was made to study the effect of main reinforcement ratio and distribution on the behavior of shallow and deep beams.

The main research outcome was establishing a suitable definition for the shallow to deep member of simple and continuous beams made of high and ordinary strength concrete. In addition, some necessary recommendations about beam design and reinforcement arrangement were suggested. Finally, the ultimate and serviceability limit states procedures for the new analytical unified design for both shallow and deep beams were proposed with their flexural design aids.

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