Amirkabir Journal of Civil Engineering

Amirkabir J. Civil Eng., 52(10) (2021) 609-612
DOI: 10.22060/ceej.2019.8777.4779

Height effect on shear strength of deep beams without Shear Reinforcement with normal and lightweight concrete

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ABSTRACT: Failure in reinforced concrete deep beams is mainly in shear and in a brittle and sudden form, which this behavior can lead to destructive consequences. So determining shear capacity of these beams is an important issue. One of major parameters in determining shear capacity of beams is the height of beam. Researches show that with increase in beam's height, normalized shear strength decreases which this phenomena is called size effect. In recent years due to advances in construction methods, the idea of using lightweight concrete deep beams has been proposed, this should be done with a full understanding of the behavior of lightweight concrete. Moreover, truss models are recently used for analysis and design of deep beams in codes which their validity for lightweight concrete should be investigated.

In this research to investigating size effect in lightweight concrete deep beams and comparison with normal concrete, two series of beams including 8 deep beam with shear span to height ratio of 0.5 were built in lab. First series included 4 beams with height of 30, 45, 60 and 90 cm using lightweight concrete in their construction, specimens of second series were similar to first but normal concrete was used in there construction. Results show that failure mode is independent of height and concrete type. The pattern of crack propagation is more affected by height and almost independent of concrete type. Normalized shear strength in both groups of beams decreases with increase in height but the intensity of this decrease in lightweight concrete deep beams is more than normal concrete which shows that size effect in lightweight concrete is more than normal concrete. Results of Experiment were compared to truss methods in codes and some of proposed models in codes. Results indicate that all methods are conservative in low height beams and with increase in height, safety margin decreases. Results of CSA code is non-conservative for beams with 90 cm height which needs more study.

Review History:

Received: 2019-07-04
Revised: 2016-01-29
Accepted: 2018-11-05
Available Online: 2019-02-06

Keywords:

Deep beam, Size effect
Lightweight concrete
Truss method
Shear capacity

1. INTRODUCTION

There are several advantages in using light-weight concrete (LWC) for a building material. The reduction of dead load due to a lower density of concrete allows for smaller and lighter-weight structural members. Reductions in the dimensions of columns and beams result in more available space, and reductions in their self-weight can improve the seismic resistance capacity of building structures [1].

Furthermore, the smaller and lighter elements of precast concrete members are preferred because the handling and transporting system becomes less expensive, and offshore structures mostly used for oil production require LWC elements to provide easier towing and greater buoyancy.1 As a result, there has been a growing interest in the practical application of LWC for structural members. Deep beams, which have useful applications as load distribution elements such as transfer girders, pile caps and foundation walls in tall buildings, are distinguished as structural members of discontinuity regions having a small shear span-to-overall depth ratio [2]. The load capacity of deep beams is governed by shear rather than flexure and shear deformations are not negligible.

A group of reinforced concrete deep beams is distinguished as a disturbed-region member where conventional beam theory does not apply due to geometric or static stress discontinuities. As most of the top loads applied to deep beams are transferred to supports through strut-and-tie action, the mode of failure and load capacity of deep beams are commonly governed by shear rather than by flexure. As a result, the size effect is an inevitable consequence, as shown in a few experimental investigations. Yang et al. concluded that the size effect becomes more significant in beams that have a smaller shear span-depth ratio because the failure of concrete struts joining the loading and support points shows more brittle behavior with the decrease of the shear span-depth ratio [3, 4]. Tan and Cheng pointed out that the size effect needs to be considered in the strut-and-tie model (STM) to appropriately evaluate the shear capacity of deep beams [5]. There is still

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controversy, however, surrounding the size effect in deep beams where LWC is used because the size effect is affected by the aggregate interlock, which can substantially contribute to the shear strength across diagonal shear cracks. Furthermore, the conservatism of STMs specified in code provisions is unconvincing because very few, if any, test results for LWC deep beams are available in the current literature [6].

2. METHODOLOGY

In this research to investigating size effect in lightweight concrete deep beams and comparison with normal concrete, two series of beams including 8 deep beam with shear span to height ratio of 0.5 were built in lab. First series included 4 beams with height of 30, 45, 60 and 90 cm using lightweight concrete in their construction, specimens of second series were similar to first but normal concrete was used in there construction.

Regarding to Iranian codes, it is not mentioned clearly how to design deep beams and only suggested to use reliable methods and codes, it can be designed. So, in this paper experimental results are compared with results of reliable code and recent studies for truss methods [7].

Results shown that in all codes and studied procedures, affection of concrete types are noticed. Referring to obtained results, to have safety edge for beams designing with varies height; it is suggested to design regarding EC2 code [8] and method of the author [2].

3. DISCUSSION AND RESULTS

The Load is applied statically with constant speed, until the final failure occurred. Two methods were used to control loading speed. In the first method, the transfer speed was controlled below the loading point (jack speed). In the second method, the loading speed was controlled, which was approximately equal to 0.25 kN/s .

By reducing the shear capacity ratio to the bending capacity, the shear capacity of the reinforced concrete member is not able to withstand the shearing stresses and will be failure due to excessive opening of the shear cracks in the beam. Such a failure is very crude and sudden. According to experimental results, the shear failure is less affected by the absence of stirrup and strength of concrete, which is most likely to occur instantaneously and with a striking sound like explosion. The failure of all specimens was shear mode so that at the final load, the width of crack that is extended between the loading point and the support was increased and caused a failure. In one of the specimens, (N-90-0.5) at the same time, the concrete cover was cut off at the final load at the same time. The crack surface in the light concrete was smoother than the normal concrete, which was due to crass the cracks within the aggregates. As the height increased, the shear strength increased, but it did not affect the failure mode. In general, the failure mode is independent of the type of concrete and height. In Figure 1, the shear failure of the beams is shown.

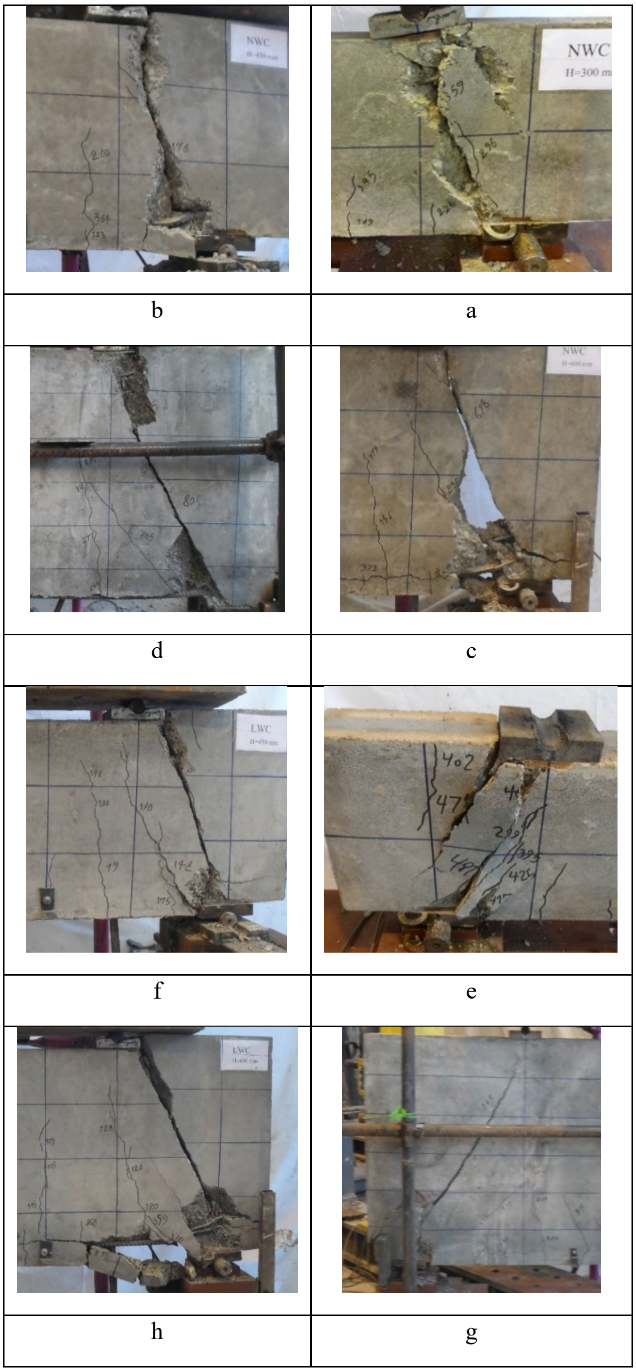

Fig. 1. Failure mode in tested beams: a) N-30-0.5 b) N-45-0.5 c) N-60-0.5 d) N-90-0.5 e) L-30-0.5 f) L-45-0.5 g-) L-60-0.5 h) L-90-0.5

4. CONCLUSIONS

The summarized results of the experimental and analysis are as follow:

1-With increasing the height of the beams, failure mode doesn't change. The crack pattern development was significantly influenced by depth but independent of the type of concrete

2-Results of ACI code [9], CSA code [10], EC2 code [8] and studied methods for beams with low height and all groups of beams are conservative.

3-Increasing the height of beams in ACI codes, CSA codes and EC2 codes, decrease the safety of them.

4-Results of ACI 318-11 ، EC2 codes and the author method for all experimental beams are conservative.

5-Results of CSA codes for height beams (90 cm) and all groups of beams are non-conservative.

6-In EC2 code, Because of using concrete special weight in calculating Resistance coefficient of concrete with light-weight, results of light-weight and normal concrete are the same.

7-Regarding mean and standard deviation, results of Arabzedeh 2009 [7] has fewest dispersion in compare with experimental results.

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HOW TO CITE THIS ARTICLE

A. Arabzade, A. Noori Soola, Height effect on shear strength of deep beams without Shear Reinforcement with normal and lightweight concrete, Amirkabir J. Civil Eng., 52(10) (2021) 609-612.

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