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Analysis of the Deflection Ratio of a Real-Life RCC Beam and Its' Half Scale Model

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Abstract

Among all structural members of a building, the beam resists load applied laterally to its axis. When imposed loads are more than the beam's capacity or exceeds its capacity, the beam deflects for those imposed loads. Deflection on a loaded beam is the vertical displacement of a point. To assess the amount of deflection of a beam, particular tests must be held. But the hardest task to test a real life beam in laboratory having its' larger cross sectional area. If it would be possible, a certain amount of deflection would be avoided by designing the beam appropriately. Testing procedures would be easier if the prototype beam is converted into small scale model. The literature substances in the application of technique for finding out such ratio, where it can be applied to sort out the real-life beam's deflection. If the scale is down to a half scale, the test procedures would be easier due of its manageable dimensions. This study provides the deflection analysis of a real-life beam and its half scale model. Moreover, the ratio of deflection between the real-life beam and half scale model will help to determine the real-life beams deflection, just by determining the deflection of its half scale model. These projections are based on certain parameters that might not always be accurate. Because of this, the real outcome could differ from the theoretical outcomes.

Keywords: *Deflection of RCC beam; deflection analysis; real life beam; half scale beam model; deflection ratio.*

1. Introduction

Beams are defined as structural members which carry all vertical loads and provide resistance from bending. Various types of materials are used when a beam is designed. For any kind of a building construction, RCC beams are mostly used. Every individual beam has its own load carrying capacity and bending resistance capacity. Loads that come directly to the beam are distributed loads or imposed point loads. When a beam exceeds its load carrying capacity, it deflects. There might be a small amount of deflection for self-weight itself. But when the intensity of imposed loads is high, the beam deflects. When a certain amount of load is applied at the midpoint of a simply supported beam, the maximum amount of deflection occurs at the midpoint of the beam. For self-weight, beam will deflect instantaneously. After that instantaneous deflection, deflection gauge has to set to measure deflection for imposed load. There are two types of deflection. One is instant and another one is long term. When loads are high enough that beam's capacity exceed, then because of corresponding loads beam will fail or deflect. There are many methods to measure the deflection of any loaded beam. Commonly used methods are Double Integration Method, Moment Area Method, Conjugate Beam Method and so on.

Fiqih [1] studied the deflection of beam where analytical and numerical method was used. In that study a wide-flange steel beams were used for different support conditions. There were differences in deflection for both analytical and numerical method. Kim [2] explored the analytical and experimental investigation based on half scale model for a cleanroom unit for both steel section and reinforced concrete where half scale model was manufactured based on a mass-based similitude law which does not require additional mass. The dynamic test using an impact hammer is conducted to obtain the transfer function of 1/2 scale model. Lee [3] investigated Experimental and Measurement Methods for the Small-Scale Model Testing of Lateral and Torsional Stability. In that study load vs vertical displacement was assess for both load and unloading condition. Ahmed [4] studied Flexural response of stainless steel reinforced concrete beam where small scale model was used and 4-point bending test was conducted. In all cited study, flexural responses, lateral and torsional stability, displacement were assessing where both steel and concrete beams were tested. In some studies, beams were chosen as small scale but there was no comparison between any real life or full scale beam with its half scale model. To meet this gap, in this study full scale and its half scale models were tested and mid-point deflection and deflection ratios were evaluated.

2. Materials & Methods

The value of deflection was measured by performing RCC beam test and material testing as per ASTM specifications. Non-mechanical properties of fine and coarse aggregates were measured and compared. For concrete production arbitrary volume method was used and the mix ratio of cement, fine and coarse aggregates was 1:2:4 where 0.5 was the water-cement ratio. For concrete production sand used as fine aggregates, brick chips used as coarse aggregates, 60 grade steel was used and Portland cement used as binding materials. For beam casting same standard concrete were used. Concrete cylinder specimen, three real life RCC beam and three half scale model beams were produced and tested after 28 days of curing. For theoretical analysis conjugate beam method and double integration method were used for both real life beam and small scale model. As it's considered that the beam section is transformed section, so the beam that is considered is made of non-homogeneous materials (RCC beam). But here in case of moment of inertia calculation, it has been considered as transformed section of the beam. That's why modulus of elasticity has been considered as modulus elasticity of concrete.

Table 1. Dimension, properties and reinforcement details of specimens

Specimen	Length (in)	Cross-section (inXin)	Moment of inertia(in^4)	Bottom reinforcement	Top Reinforcement	Stirrup		Compressive Strength Of concrete
						At support	At mid span	
RLB-1	60	8X10	700.14	3-16mm	2-16mm	10mm@4"	10mm @6"	2000 psi
RLB-2	60	8X10	700.14	3-16mm	2-16mm	10mm@4"	10mm @6"	2000 psi
RLB-3	60	8X10	700.14	3-16mm	2-16mm	10mm@4"	10mm @6"	2000 psi
HSM-1	30	4X5	43.098	2-10mm	2-10mm	10mm@4"	10mm @6"	2000 psi
HSM-2	30	4X5	43.098	2-10mm	2-10mm	10mm@4"	10mm @6"	2000 psi
HSM-3	30	4X5	43.098	2-10mm	2-10mm	10mm@4"	10mm @6"	2000

Based on the maximum moment resisting capacity the reinforcements were designed. To keep the beam always wet the beams were covered by jute bag. When 28 days curing was done, then those beams were shifted to the lab for testing.

3. Experimental work

At the very beginning of the study different ingredients of concrete were collected. As Sylhet sand provide better performance which was assessed by earlier study [5], then its' used as fine aggregates. Brick chips were used as coarse aggregates. Non- mechanical properties such as bulk unit weight, specific gravity, absorption capacity of aggregates were evaluated. Table-1 provides all materials testing specification as per ASTM.

Table 2. List of test specifications

Investigation	Test Specifications
Sieve Analysis	ASTM C136 [6]
Specific gravity and absorption capacity(coarse aggregates)	ASTM C127[7]

Specific gravity and absorption capacity(fine aggregates	ASTM C128 [8]
Bulk unit weight	ASTM C29 [9]
Slump test of concrete	ASTM C143 [10]
Compressive strength of concrete	ASTM C39 [11]
Flexural Strength of Concrete (Using Simple Beam with Center Point Loading)	ASTM C 293/C 293M[12]

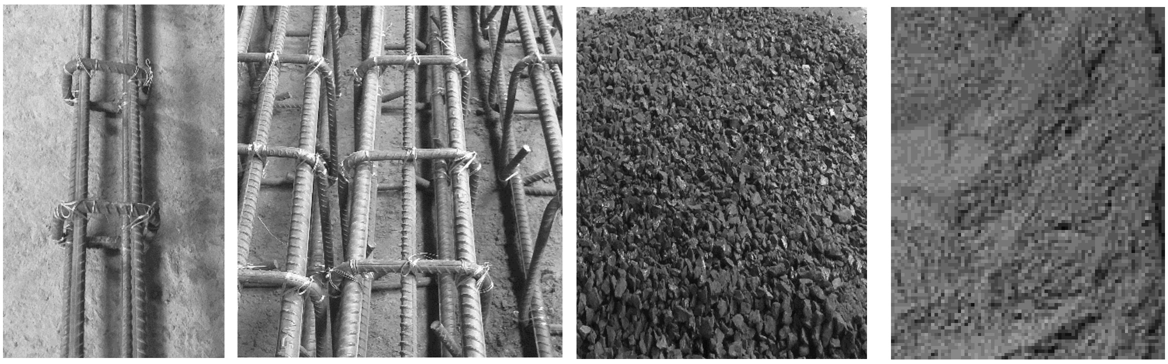

Figure 1. Materials used in this study

To conduct the second phase of experimental work, the initial task was to set the beam following all laboratory criteria for experiment. Beams were placed on the moveable crane in such a way so that both supports were in the same amount of distance from the face of each beam. Then the beams were moved to the UTM (Universal testing machine) for the experiment work.

Figure 2. Laboratory task while conducting test of specimens

4. Result and Discussion

Physical properties of the aggregates, the workability of fresh concrete in terms of slump value and unit weight of concrete were measured and tabulated in table 3. The absorption capacity of brick chips was found to be substantially higher as it's obtained from clay bricks. It should be noted that the characteristics of brick chips and sand collected from various source can differ. To verify the workability of produced concrete slump value was measured and found 6.5 inch where water-cement ratio was 0.5. As the specific gravity of brick chips was lower, the unit weight of produced concrete found to be lower as well. 28-days mature concrete cylinder were tested and the compressive strength of concrete was found 2000 psi. The theoretical analysis of deflection was conducted based on that compressive strength data.

Table 3. Properties of aggregates and concrete

Material	Specific gravity			Bulk unit weight(pcf)	Absorption(%)	Slump value(in)	Unit weight of concrete(pcf)
	Bulk dry	Bulk SSD	Apparent				

Brick chips	1.33	1.59	1.78	71	16	6.5	120
Sand	2.55	2.61	2.67	101	1.2		

As 3 real life beam were tested for determining the deflection at midpoint, after averaging the deflection result of those beams the optimum results are presented in table 4. The cracks started propagating after applying 77.84 KN load and it deflected fully at 111.2 KN. The crack pattern and depths were beyond the scope of this study. From the tabulated data it's found that up to 66.72 KN the data difference between theoretical and experimental deflection was not significant and there observe gradual increase in deflection value. From 77.84 KN to 111.2 KN, the data differs significantly.

Table 4. Theoretical and experimental deflection of real life beam

Load (KN)	Theoretical Deflection(mm)	Experimental Deflection(mm)
11.12	0.2495	0.206667
22.24	0.499	0.375
33.36	0.7485	0.486667
44.48	0.64	0.683333
55.6	0.8	0.838333
66.72	0.96	1.073333
77.84	1.12	1.326667
88.96	1.28	1.693333
111.2	1.6	1.796667

Both theoretical and experimental results of half scale model are tabulated in table 5. The maximum load caring capacity of half scale model was found 33.36 KN and it's got deflected fully. The experimental deflection results are somewhat lower than theoretical deflection. The shear reinforcement of half scale models were same as real life beam model. Because of this, the experimental deflection data was found lower. It should be emphasized that the major focus of this study is just the variety of deflection outcomes.

Table 5. Theoretical and experimental deflection of half scale model

Load (KN)	Theoretical Deflection(mm)	Experimental Deflection(mm)
11.12	0.2495	0.16
22.24	0.499	0.365
33.36	0.7485	0.666667

As the maximum load carrying capacity of half scale model was found 33.36 KN. So, to evaluate the deflection ratio the maximum load for both real life and half scale model was kept 33.36 KN. The deflection ratio using theoretical analysis for both real life and half scale model was tabulated in table 6. It was found that for all applied load up to failure the deflection data is almost same which indicate that there's no significant impact of beams' cross section whether it's real life or half scale model. In this case by testing a half scale model of any real life beam model the probable or approximate deflection could be determined easily.

Table 6. Deflection ratio of theoretical deflection between RLB and HSM

Load (KN)	Theoretical Deflection(mm); RLB	Theoretical Deflection(mm); HSM	Deflection Ratio
11.12	0.16	0.32	0.5
22.24	0.32	0.65	0.4923077
33.36	0.48	0.975	0.4923077

The experimental deflection ratios for both real life and half scale model are presented in table 7. Tt's shown here that the deflection ratios aren't exactly same as theoretical analysis. But there might be a range or limit of deflection ratio & from that ratio it would be easier to determine the probable deflection of a real life beam model by testing a half scale model of that real life beam. The values of theoretical and experimental deflection data for the same amount of imposed load aren't same.

Table 7. Deflection ratio of experimental deflection between RLB AND HSM

Load (KN)	Experimental Deflection(mm); RLB	Experimental Deflection(mm); HSM	Deflection Ratio
11.12	0.206667	0.16	1.2916688
22.24	0.375	0.365	1.0273973
33.36	0.486667	0.666667	0.7300001

5. Conclusion

In case of theoretical analysis, the deflection of real life beam model is around 0.5 times of the half scale beam model for a particular concentrated load. Though imposed loads are gradually changed but the deflection ratios remain same as before. On the other hand, from the experimental data table it's observed that the deflection ratios have changed for any arbitrary value of imposed load. Different deflection ratios imply that it's won't be easier to sort out the deflection of any real life beam model only by testing its half scale model. In building construction or any kind of structural analysis it's a toughest task to analyze or test a full-scale model in laboratory because of its larger dimensions. To solve this problem testing a half scale model would be a wise approach to conduct further analysis of beams. But in both theoretical and experimental analysis no precise ratio was found out to assess the deflection of real-life beam model by testing its half scale model. It should be emphasized that all of the above conclusions are based on aggregate samples and beam specimens used in this investigation. Several aspects of this research necessitate further consideration. Variability should be investigated in similar tests with bigger batch sizes. The durability of the used concrete, as well as its long-term impact on the manufactured beams, should be explored, which was beyond the scope of this study.

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