

The Effect of Cracking on the Dynamic Modulus of Reinforced Concrete Beams

MEng Group 11



Introduction

In recent decades, structural engineers have refined their understanding of material and structural behaviour, which has had consequences on the dynamic behaviour of modern structures:

- Structures have becoming increasingly slender.
- This reduction in material results in a lower member mass, and therefore a lower natural frequency.
- Structures may experience vibration above the acceptable limit as a consequence of people walking or other excitations.

Good design against these issues requires better understanding of the dynamic modulus of a reinforced concrete slab.

Theoretical and Computational Predictions

- Predictions regarding the development of cracks, displacement and frequencies have been achieved through utilising **Excel**, **MATLAB** and **GSA Oasys** (Models shown in Fig. 5).
- Difficulties in prediction arise with determining the extent of cracking in a concrete beam. A higher extent of cracking across the beams cross-section leads to a lower second moment of area. As the amount of cracking cannot be accurately predicted, the behaviour of the beam is difficult to anticipate with certainty thus must be experimentally found and verified.
- The predictions have been made using two limiting boundary conditions: a fully cracked section and an uncracked section – the experimental results will fall within this range.
- It is expected that initial natural frequencies of the beams will be approximately **4.5 to 6.5Hz**, decreasing to **1.5 to 2.5Hz** at max loading of a 3m beam. The largest deflection is predicted at **~140mm** and max crack widths at **1.7mm**.
- Quantifying the extent of cracking is necessary to determine the changes in second moment of area coupled with experimental dynamic testing the beam will be used to determine the effects of cracking on the dynamic modulus of a concrete beam.

Design of Beams, Concrete and Rig

- Three cantilever beam lengths will be tested – **3.0m, 2.5m and 2.0m**. Each cantilever length will comprise three specimens totalling **9 beams**. The beams cross-section are kept constant at **300mm wide by 100mm deep**.
- The aim is to design a concrete mix and reinforcement typical of that used in industry: **Concrete grade 32/40** (cylinder/cube) and **singly reinforced with 2H12** ribbed longitudinal bars ($A_{s,prov}=226mm^2$). No shear reinforcement/ links are required instead, **transverse reinforcement of H8-300mm** will be provided typical of a reinforced concrete slab.
- The design of the Reinforced Concrete section and mix are in accordance with **Eurocode 2**.
- The concrete was mixed and cast in the Engineering Laboratory using reusable wooden moulds and will be cured for a minimum of 28 days prior to testing.
- Once cured, the beams will be craned into the testing rig. 300mm of the beam will be clamped thus requiring a casting length 300mm longer than the cantilever length.
- Two rigs have been constructed, using steel meccano, to allow the beams to be tested simultaneously which reduces the testing time required.

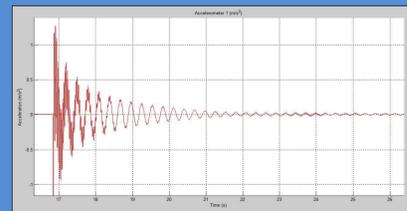


Figure 1 - Preliminary Graph of Acceleration of the Free End

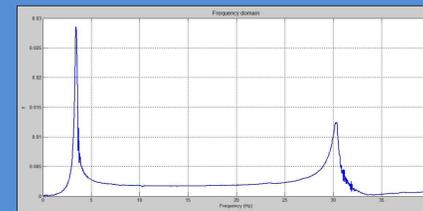


Figure 2 - Frequency Response of the Preliminary Beam

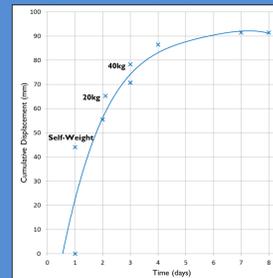


Figure 3 - Preliminary Study, 3.0m Beam: Displacement over 8 Days



Figure 4 - Observed Cracks on the Top and Sides of the Preliminary Beam

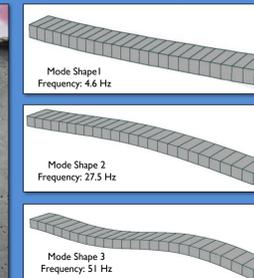


Figure 5 - GSA Beam Mode Shape Predictions: Modes 1, 2 and 3



Aims and Objectives

- To determine a relationship between the dynamic modulus and the extent of cracking by building and dynamically testing a number of RC beams of varying natural frequencies subjected to a number of different static loading conditions.
- Determine the relationship between amplitude of vibration relates to cracking.
- Determine how altering the percentage of reinforcement, grade of concrete and type of aggregate effects the dynamic properties of an RC beam using GSA Oasys software

Preliminary Study: Frequencies, Cracking and Displacement

- A preliminary study is currently on-going. Frequencies, cracking and displacement of this 3 m cantilevered beam is being recorded over a period of 10 days.
- This will be achieved through increasing the end load of the cantilevered concrete beam ultimately resulting in an increase in bending moment and cracking of the upper surface of concrete subject to tensile forces.
- At each increase in load, a series of hammer impact tests will be conducted to determine the natural frequencies of the beam. Three accelerometers will be strategically positioned on the beam/ rig to capture vertical accelerations (Fig. 1) and a frequency spectral resolution will illustrate the natural frequencies of the beam (Fig. 2).
- Widths, length and depth of cracks developing transversely across the concrete surface are measured using a crack microscope with a maximum resolution of 1/20mm (Fig. 4)
- The displacement of the free end is accurately measured using a displacement gauge at regular time intervals. The current displacement so far is shown in Fig. 3.
- The natural frequencies will be correlated with the recorded displacement and crack data to achieve the project objectives.

Current Progress: High Level Project Timeline

Action	Week																							
	1	2	3	4	5	6	7	8	9	10	15	16	17	18	19	20	21	22	23	24				
Design of RC Beam, Rig and Testing	█																							
Prepare Dynamic Analysis																								
Produce GSA Oasys Model																								
Cast 9 Beams: 2.3m, 2.8m & 3m																								
Testing of Beams and Data Processing																								
Analysis of Results comparing with Theory																								
Report Writing																								

NOTE: We are currently on schedule on all high level actions apart from the testing of beams and casting due to delays caused by logistical issues in the laboratory. Testing is now expected to start in Week 17.