

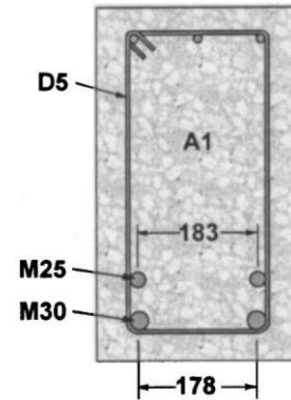
**Nonlinear Modeling of Reinforced Concrete
Video Handout 1 (Nonlinear Frame Analysis using SAP2000)**

A simply-supported reinforced concrete beam has details shown below. Results from steel coupon tests for reinforcing bars are summarized in the tables below, along with the cross-sectional properties of the bars. From standard test cylinders, the compressive strength of the concrete was found to be **22.6 MPa** (3.28 ksi) at the time of the beam test.

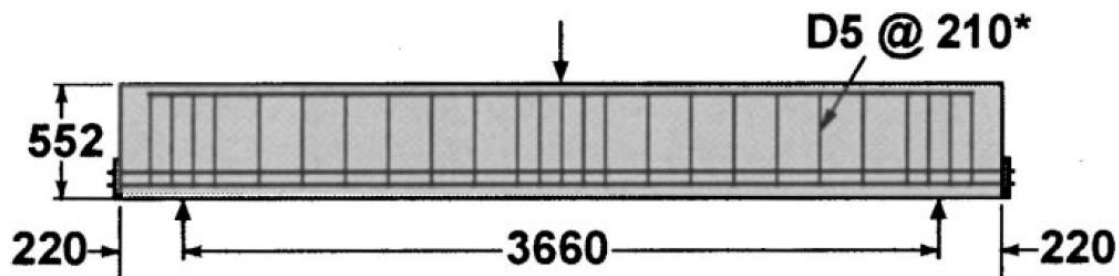
An assessment is required of the expected behaviour of the beam. Specifically, you are required to estimate the following: **(a)** cracking load, P_{cr} ; **(b)** ultimate load, P_u ; **(c)** mid-span deflection at failure, δ ; and **(d)** crack pattern and failure mode.

Reinforcement					
Bar size	Diameter (mm)	Area (mm ²)	f_y (MPa)	f_u (MPa)	E_s (MPa)
M10	11.3	100	315	460	200,000
M25 ^a	25.2	500	440	615	210,000
M25 ^b	25.2	500	445	680	220,000
M30	29.9	700	436	700	200,000
D4	3.7	25.7	600	651	200,000
D5	6.4	32.2	600	649	200,000

Concrete				
Beam number	f'_c (MPa)	ϵ_0 (mm/mm)	E_c (MPa)	f_{sp} (MPa)
A1	22.6	0.0016	36,500	2.37



Beam number	b (mm)	h (mm)	d (mm)	L (mm)	Span (mm)	Bottom steel	Top steel	Stirrups
A1	305	552	457	4,100	3,660	2 M30, 2 M25	3 M10	D5 at 210



Note: SI units are used in the questions. Solutions can be made using either SI or U.S. customary units. For simplicity, take **1 in. = 25 mm**