Effects Of Camber Of Beam On Behavior Of Single Span Portal Frames

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Abstract

An attempt is made to study the effect of camber on the behavior (deflection and failure load) of single span portal frames under concentrated load. Two types of cambering were used, the first by cambering both top and bottom surfaces of the beam and the second by cambering the bottom surface only (the top surface is kept leveled) which is more acceptable from point of view of uniformity of super imposed dead load distribution.

There is a considerable effectiveness of the camber on the failure load compared with straight beams (without camber). Also, there is effectiveness considering (dead+live) load deflections for cambered beams compared with straight beams.

Keyword : Membrane Action, Camber, Concentrated Load, Deflection, Failure.

تأثير تحدب الجسور على سلوك الهياكل احادية الفضاء

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الخلاصة

تضمن البحث دراسة تأثير تقوس العتبات (نحو الأسفل) على تصرف (الأنحراف "الأود" وحمل الفشل) لهياكل حاملة أحادية الفضاء تحت تأثير حمل مركز. تم أستخدام نوعين من التقوس ، الأول بعمل التقوس للسطحين العلوي والسفلي للعتبة والثاني بعمل التقوس للسطح السفلي فقط (مع إبقاء السطح الأعلى مستوياً) والذي هو أكثر قبولا من ناحية التوزيع المنتظم للحمل الميت الأضافي.

أظهرت النتائج تأثير واضح للتقوس على حمل الفشل بالمقارنة مع العتبة المستقيمة (بدون تقوس). وكذلك ظهر تأثيرالتقوس على قيم الأنحرافات تحت تأثير الحمل الميت والحي بالمقارنة مع العتبة المستقيمة.

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Introduction

Reinforced concrete is considered (due to its durability, relative low cost and relative high compressive strength) as one of the most important structural materials.

Restrained forces (at the ends of a member) may be mobilized if some camber (arching by shallow curvature) is introduced to flexural members (beams or slabs). This axial restraint acts in a similar manner as an axial pre-stressing force [1].

The maximum permissible deflection may be exceeded if camber is provided so that the total deflection minus camber do not exceed the permissible limit [2,3].

Membrane action (axial restraining force) is activated due to actual restraint at the ends of the beams (straight or cambered) [4]. The influence of membrane action cannot be ignored [5]. Particular attention was paid to the contribution of compressive membrane action to the load carrying capacity [6].

Scope Of Research

An attempt is made to study the effect of camber on single span portal frames with beams (cambered at bottom surface and leveled at top surface).

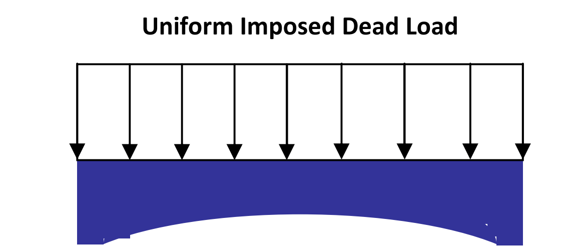


Fig. (2) Uniform Dead Load Distribution.

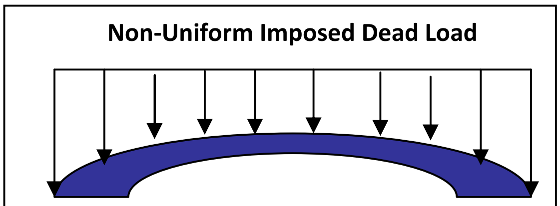


Fig. (1) Non-Uniform Dead Load Distribution.

The previous researches [1 , 4] dealt with beams that are cambered at top and bottom surfaces. This case of cambering will cause the imposed dead loads (tiles and the materials beneath tiles) to be applied in non uniform manner across the beam span, Fig. (1).

In this study, the cambered models investigated are more practical from point of view of uniform imposed dead load application and in reducing the amount of concrete used, Fig. (2).

The previous researches [1,4] dealt with beams that are subjected to uniformly distributed loads, while in the present study, an attempt is made to investigate the effect of camber on the behavior of beam under the concentrated load.

Five models were cast, frame (F1) (with straight beam) as the basis of design and comparison, frame (F2) (with cambered beam where top and bottom surfaces are to be cambered) as the basis of comparison with frames (F3), (F4) and (F5) where the bottom surface of the beams is cambered only. The shape and frame configuration are given in Appendix (A) and the design details are given in Appendix (B).

Computer Analysis

Before the experimental work was conducted, a computer plastic analysis (using P-FRAME software) was performed to check (theoretically) the applicability and effectiveness of the suggested cambered models. Geometric details, material properties, node numbering, some of the results are given in APPENDIX (C).

Deflection Calculation

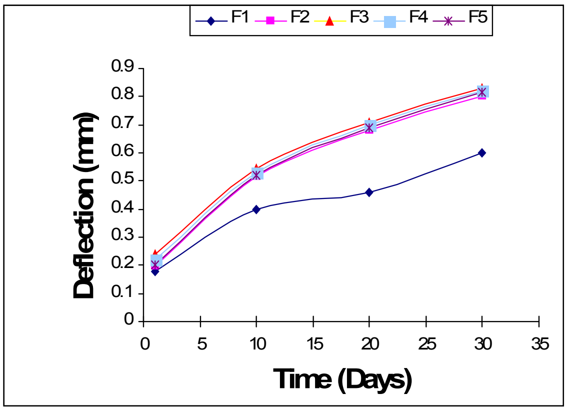
The five frames were subjected to dead load (P_{DL} = 5.60 kN) for 30 days and the deflection readings were measured and are given in **Table (1)**.

Table (1) Actual (measured) deflection due to dead loads

	Deflection (mm)

Frame	(1) Day +	(10) Days	(20) Days	(30) Days
F1	0.180	0.399	0.461	0.599
F2	0.196	0.514	0.681	0.802
F3	0.240	0.546	0.709	0.830
F4	0.222	0.531	0.700	0.821
F5	0.203	0.521	0.687	0.816
+ Measured from the time of application of imposed dead loads.				

It can be seen that the deflections of the cambered frames are greater than those of the straight frame. This is may be because the membrane forces have not been activated yet, and this is due to the small deflection occurs. It can also be seen that frame (F5) is the best frame among (F3, F4 & F5) compared with frame (F2). Fig (3) shows the relation between deflections due to dead loads only with time in days



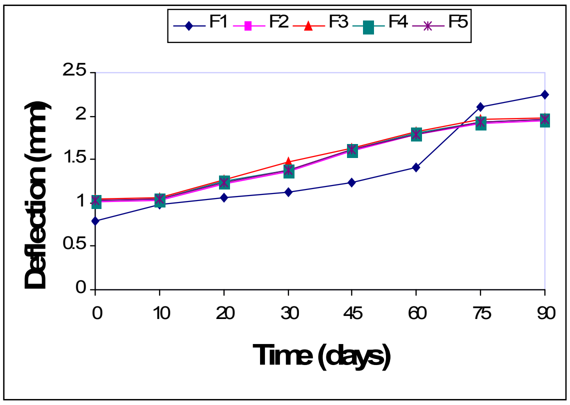


Fig.(3) Deflection-Time relation under imposed dead loads only

Fig. (4) Deflection-Time relation dead & live loads.

Fig (4) shows the relation between deflection due to dead and live loads with time in days.

After 30 days of the application of imposed dead loads, another load (P_{LL}= 6.574 kN) was applied as live load and the deflection readings were measured and are given in Table (2).

Table (2) Actual (measured red) deflection due to dead and live loads

	Deflection (mm)							
	1 day+	10 day	20 day	30 day	45 day	60 day	75 day	90 day
Frame	0.788	0.979	1.067	1.116	1.239	1.411	2.109	2.247
F2	1.015	1.028	1.217	1.366	1.600	1.788	1.916	1.952
F3	1.046	1.059	1.258	1.474	1.625	1.812	1.955	1.982
F4	1.036	1.045	1.243	1.382	1.619	1.802	1.938	1.969
F5	1.024	1.037	1.230	1.373	1.608	1.793	1.925	1.959

+ Measured from the time of application of live loads.

It can be seen that up to 70 days [from the application of live load], the total deflection of cambered frames is still greater than that of the straight frame. After 70 days, there is a change in behavior, where the total deflection of cambered frames is now less than that of straight frame. It seems that the membrane action (restraint force) is being mobilized (after 70 days) in such a manner to act as a pre-stressing force increasing the compressive strength of the cambered frames, while in straight frames there was no such increasing in compressive strength.

Failure Loads

After 90 days from application of live loads, all the frames (F1, F2, F3, F4 & F5) were subjected to load increment (which was applied for all frames at the same time) until failure. The actual failure loads are given in Table (3) and are shown in chart diagram shown in Fig.(5).

Table (3) Failure loads

Frame	**F1**	**F2**	**F3**	**F4**	**F5**
Failure Load (kN)	16.001	17.250	16.675	16.970	17.110

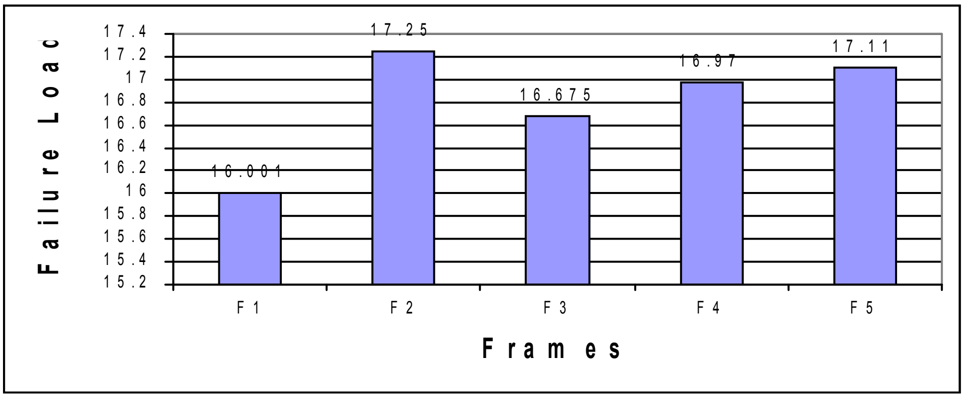


Fig. (5) Failure loads of all frames.

It can be seen that cambered frame (F2) is the best frame among all frames and this is expected due to the effect of the membrane action in increasing the load carrying capacity [1,4] and because there is no change (reduction) in beam section.. Another point to be noticed is that all of the cambered frames are better than straight frame in load carrying (up to failure). Again (F5) is the best frame that gives results approaching those of frame (F2).

Table (4) gives the effectiveness (considering failure load) of each of the cambered frames (F3, F4 & F5) compared to frames (F1, F2).

Table (4) Effectiveness (due to failure load)

Frame	F1	F2	F3	F4	F5
Failure Load (kN)	16.001	17.250	16.675	16.970	17.110
Effectiveness (Considering failure load)					

Comparing with (F1)	1.00	1.08	1.04 [+]	1.06	1.07
Comparing with (F2)	0.93 [++]	1.00	0.97	0.98	0.99

[+] Effectiveness = (16.675 / 16.001) = 1.04

[++] Effectiveness = (16.001 / 17.250) = 0.93

The application of the loads (Dead, Live and Failure) on the models were performed actually using concrete blocks, bricks, sags of gravel.

Computer plastic analysis (**P-FRAME**) is performed by applying (on each frame) the actual failure load. Some of the results are given in **Table (5)**.

Table (5) Computer plastic analysis (P-FRAME) for failure load

Frame	Failure Load (kN)	ΔV12 (mm)	Load Factor	Joints of Plastic Hinge
F1	P = 16.001	1.290	0.6098	12
		2.724	0.7608	22
		2.724	0.7608	2
F2	P = 17.250	1.342	0.5517	12
		3.060	0.7607	22
		4.088	0.7313	2
		37.713	0.7387	23
F5	P = 17.110	1.630	0.3235	12
		4.308	0.5253	22
		4.308	0.5253	2
		47.903	0.5331	23

It can be seen that the frame (F1) which is straight needs three plastic hinges to reach failure while frames (F2 & F5) that are cambered need four plastic hinges to reach failure. This was noticed experimentally, where the straight frame (F1) collapsed first then, after some load increments, the cambered frames (F2, F3, F4 & F5) collapsed each in its turn. This is because the straight frame (F1) after three plastic hinges will transform into unstable beam condition (horizontal beam with three hinges on straight line) [7] while the cambered frames (F2 & F5) after three plastic hinges will transform into three hinged arch which is stable.

Conclusions

1- Cambered beams (frames) are better than straight ones under concentrated load (considering long time dead + live deflection and failure load).
2- Cambered beams with top surface being leveled are more practical (from the point of view of uniform super imposed dead load distribution) than cambered beams with top and bottom surfaces being cambered.
3- Cambered beams with top and bottom surfaces being cambered is the best beams considering long time dead + live deflection and failure load.

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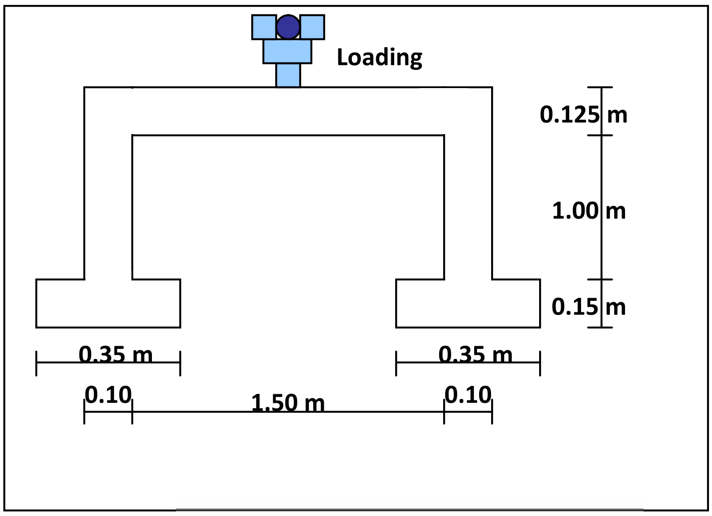
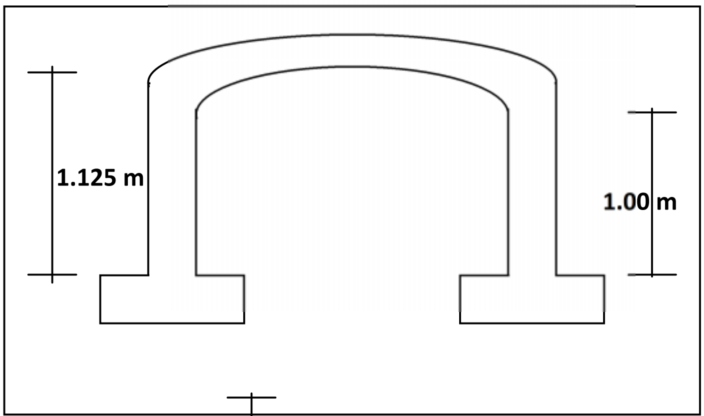
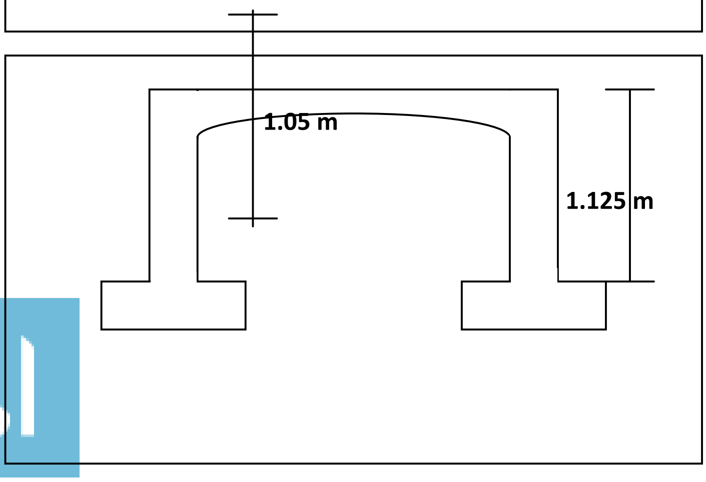
APPENDIX (A)







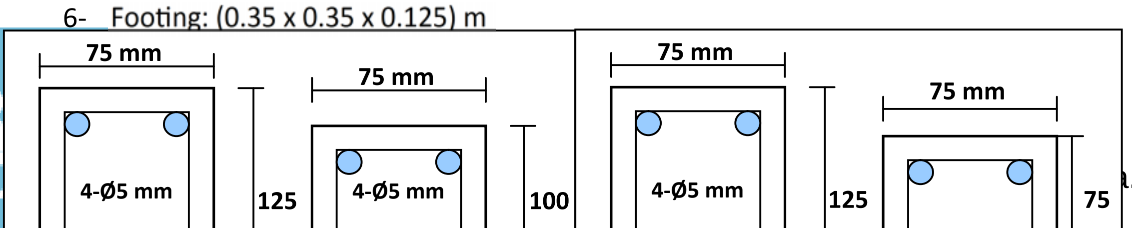
APPENDIX (B)

The actual dimensions of the members (preliminary analysis & design) were as follows:

1- Beam: (300 x 500)mm & Span = 6.0m.
2- Column: (300 x 400)mm & Height = 4.0m.
3- Footing: (1.4 x 1.4 x 0.45) m

The dimensions of the members for the models of the present study were chosen to be (1/4) scale of that of the actual frames. Hence, the dimensions for frames F1 & F2 (the basis for comparison) are:

4- Beam: (75 x 125)mm & Span = 1.5m.
5- Column: (75 x 100)mm & Height = 1.0m.
6- Footing: (0.35 x 0.35 x 0.125) m

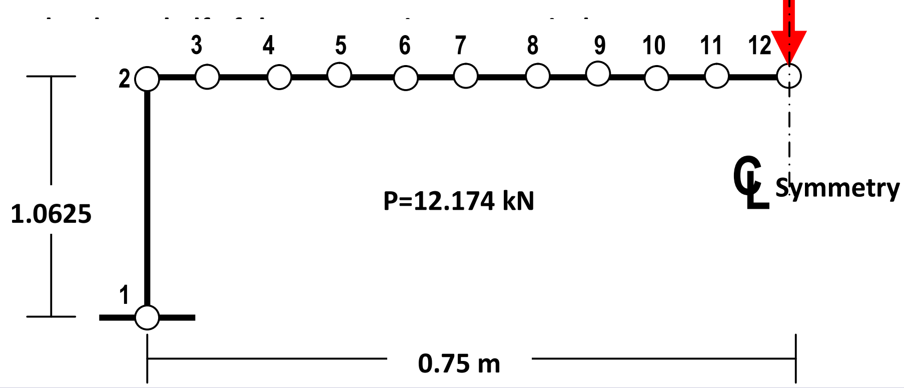


75
mm

APPENDIX (C)

Frame Geometry

NOTE: **In computer analysis, full structure was taken,**



Computer plastic analysis (P-FRAME)

Frame	ΔV12 (mm)	Load Factor	Joints of Plastic Hinge	Beam Axial Force at: (kN)	
				Member 2-3 [+]	Member 11-12 [++]
F1	1.442	0.719	12	1.411	1.411
	4.421	1.000	22	3.218	3.218
	4.421	1.000	2	3.218	3.218
F2	1.345	0.782	12	2.270	1.699
	3.062	1.001	22	3.750	3.033
	4.097	1.036	2	4.098	3.332
	37.717	1.047	23	5.063	4.297
F5	1.634	0.455	12	1.929	1.594
	6.477	0.967	4	5.535	4.834
	6.477	0.967	20	5.535	4.834
	89.061	0.980	1	7.017	6.317

[+] At the beginning of the beam.

[++] At mid-span of the beam.

[**M_p** Calculation for frame (**F1**)]

Beam: M_p = 2.2826 kN.m

Column: M_p = 3.3131 kN.m