Some Studies on Non-conventional Structural Element Hybrid Frames

(Ms) M Vahini, *Non-member*

Prof V S Jagadeesh, *Member*

Prof (Dr) D S Prakash, *Non-member*

Hybrid structures are those, which are a combination of two different types of structural elements, may be in material or in layout and structural behaviour, acting as a single structural element. Literature review has revealed that no research has been done on the concept of hybrid frame construction. The present paper reports the role played by hybrid structures in reducing the depth of beam for long span structures. Results of the study indicate that the depth of the beam can be reduced to 50% with a hybrid of conventional portal frame and gable frame.

Keywords **:** Long span beams; Depth of beam; Hybrid frames

INTRODUCTION

For long span beams, as used in auditoriums, stadium, conference halls, etc, large beam depths are required and these beams will dominate the open space, posing a problem in providing the required head room. If the beam depth is restricted it becomes uneconomical as double reinforcement becomes necessary. In such situations, hybrid frames may be thought of as alternatives. Hybrid construction or mixed construction is now being used in majority of multistorey buildings, once the traditional domain of cast-in-situ concrete and structural steelwork.

Literature review reveals that some research has been done on the hybrid construction with different materials, *ie*, a combination of *in situ* and precast, reinforced cement concrete and pre-stressed concrete etc, but not on structural elements of different layout and structural behaviour acting together. Aouad and Barret of Salford University, United Kingdom, have conducted a research on feasibility of using hybrid concrete structures, *ie*, a combination of *in-situ* and precast within the context of cost and time[1]. Research clearly shows that initial costing of hybrid concrete construction is not the only factor to be considered when adopting this or any other type of construction technology. It is the combination of construction time, cost, operational cost, process, type of procurement and other many factors, which can determine which type of construction, should be selected when faced with an array of alternatives. In the present study, finite element analysis of portal-gable frame and portal-arch frame, *ie*, a hybrid of structural elements with different layout and structural behaviour has been carried out and the results are compared with those of conventional portal frame.

(Ms) M Vahini and Prof V S Jagadeesh are with the Department of Civil Engineering, SJM Institute of Technology, Chitradurga 577 502; while Prof (Dr) D S Prakash is with the Department of Civil Engineering, University BDT College of Engineering, Davangere 577 004.

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GEOMETRY, MATERIAL PROPERTIES AND METHOD

Rise of the arch and gable frame are taken as the varying parameters. The rise varies from 0.5 m to 1.5 m with an increment of 0.25 m. Table 1 gives the sections of different elements of the frame. Span of the frame is taken as 15 m and the height as 3.6 m.

Young's modulus of M_{20} concrete as per IS: 456-2000 is taken as 22.36×10^6 kN/m^2. Poisson's ratio is taken as 0.18.[4] Finite element software STAAD.Pro is used for the analysis. 3D beam elements were used to model frame members. A uniformly distributed load of 30 kN/m is applied on the frame for analysis[3]. Columns are assumed to be fixed. Figures 1 to 3 show finite element models for portal frame, portal-gable frame and portal-arch frame.

Table 1 Cross section of different elements of the frame

Element	Breadth, m	Depth, m
Beam for portal frame	0.38	0.90
Beam for hybrid frames	0.23	0.45
Columns	0.38	0.60
Gable beam and arch	0.23	0.30

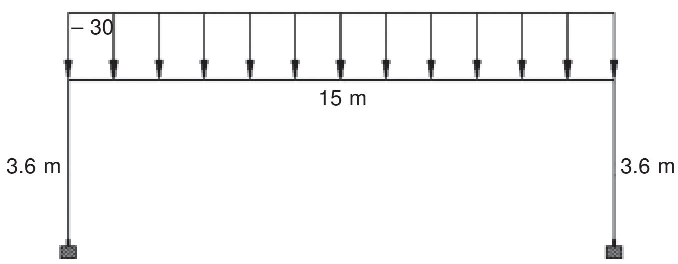

Figure 1 Finite element model of portal frame

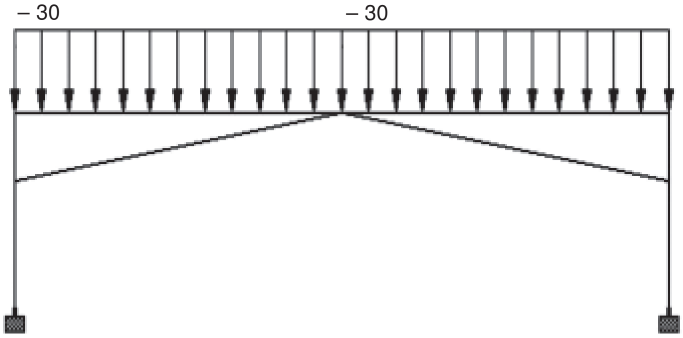

Figure 2 Finite element model of portal-gable frame

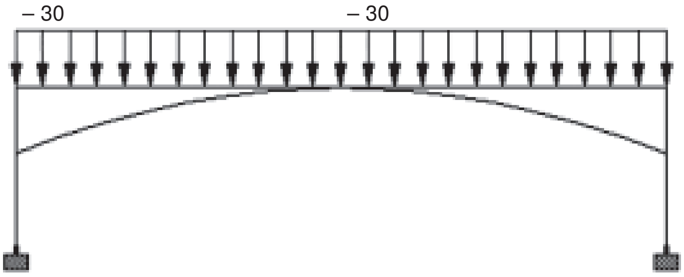

Figure 3 Finite element model of portal-arch frame

RESULTS AND DISCUSSIONS

Comparison of bending moment with respect to portal frame is made in Tables 2 and 3 and the variation of bending moment for portal-gable frames and portal-arch frames are shown in Figures 4 and 5.

Table 2 Comparison of portal beam support moments for portal frame, portal-gable frame and portal-arch frame

Portal frame	Portal-gable frame				Portal-arch frame		
Support moment, kN-m	Pitch	Rise, m	Support moment, kN-m	Change, %	Rise, m	Support moment, kN-m	Change, %
391.00	3°48′	0.50	350	–10.48	0.50	355	–9.20
	5°42′	0.75	289	–26.10	0.75	306	–21.74
	7°35′	1.00	243	–37.85	1.00	272	–30.43
	9°27′	1.25	209	–46.55	1.25	249	–36.32
	11°18′	1.50	186	–52.43	1.50	233	–40.41

Table 3 Comparison of portal beam maximum positive moments for portal frame, portal-gable frame and portal-arch frame

Portal frame	Portal-gable frame				Portal-arch frame		
Maximum positive moment, kN-m	Pitch	Rise, m	Maximum positive moment, kN-m	Change, %	Rise, m	Maximum positive moment,	Change, %
453	3°48′	0.50	147.0	–67.55	0.50	149.0	–67.10
	5°42′	0.75	118.0	–73.95	0.75	124.0	–72.63
	7°35′	1.00	101.0	–77.70	1.00	110.0	–75.72
	9°27′	1.25	92.3	–79.62	1.25	102.0	–77.48
	11°18′	1.50	86.6	–80.88	1.50	95.4	–78.94

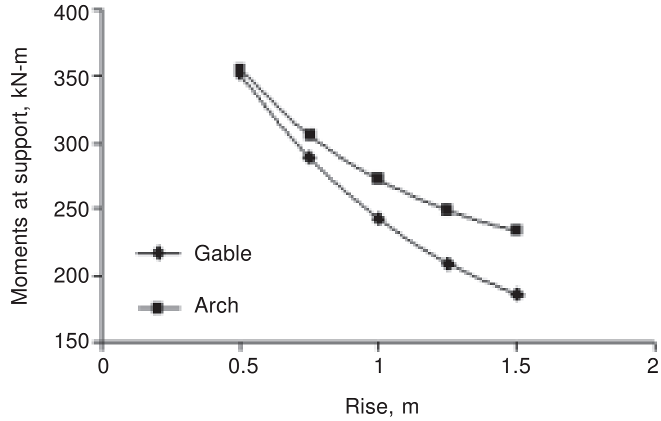

Figure 4 Variation of portal beam moments at support for portal-gable frame and portal-arch frame

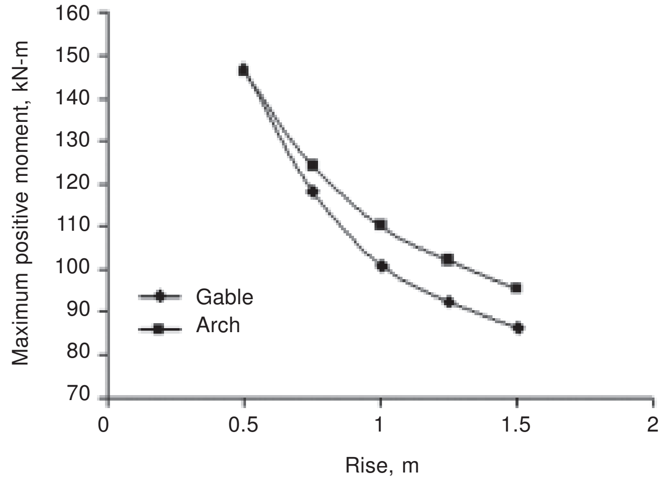

Figure 5 Variation of portal beam maximum positive moments for portal-gable frame and portal-arch frame

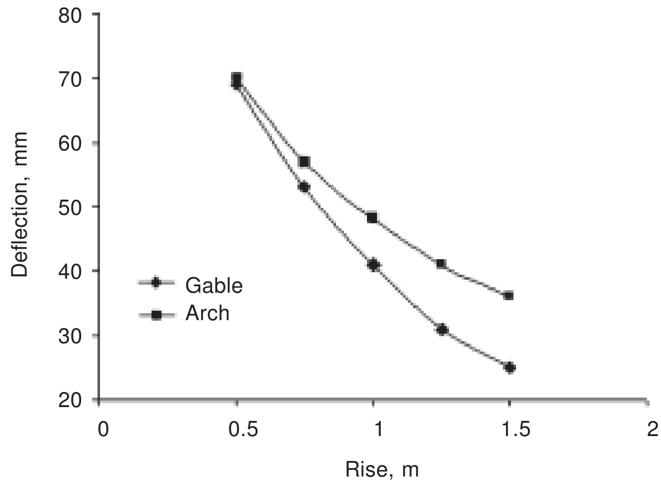

Figure 6 Variation of deflection of portal beam for portal-gable frame and portal-arch frame

Portal Beam Moments

Support moment of portal beam reduces by a maximum of 52.43% in case of portal-gable frame and by 40.41% in case of portal-arch frame in comparison with conventional portal frame. Positive moment in span reduces by 80.88% and 78.94% in case of portal-gable frame and portal-arch frame, respectively. In case of gable frame, the inclined beam will act as beam-column, attracting more axial forces than moments, whereas in case of arch, because of partial curvature, reduction in moments is less.

Deflections

It is also observed from the study that deflection of the portal beam reduces by 60% if the cross section of portal beam is maintained constant for both conventional portal frame and hybrid frames. Variation of deflection for hybrid frames is shown in Figure 6.

CONCLUSIONS

- Portal-gable frame shows a higher reduction of support moment and maximum span moment in portal beam when compared to that of conventional portal frame.
- Hybrid frames show a reduction in deflection of portal beam.
- Hybrid structures maximize the structural and architectural advantages in combining components made of different materials or of different layout and structural behaviour.
- Hybrid construction meets industry requirements for increased prefabrication, increased off sight activity, safer and faster construction.
- Hybrid frames may need stiffer columns compared to conventional frames, however, the functional requirements are more in focus in this study.

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