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Understanding Structural Movernent Joints with CAAD Animation

Dr. Arthur Lyons and Revd. Dr. Charles Doidge

Department of Architecture, School of the Built Environment,
De Montfort University, The Gateway, Leicester LE1 9BH U.K.
Tel. (0) 533 551551 Fax. (0) 533 577440

Abstract

The well-established use, as an architectural design tool, of computer graphics using 'fly-through' techniques gives a highly visual overview of design concepts and may additionally illustrate certain specific details, but it cannot show their time-dependent dynamic function.

This paper describes and illustrates how CAAD animation can be used to analyse not only structural philosophy but also the dynamic effects of non-static loading and thermal movement, thus leading to a better understanding of the design criteria applied in certain elegant solutions.

The CAAD video animations illustrate the structural philosophy relating to the façade of the refurbished Bracken House, London and the dynamic operation of key movement junctions within Stansted Airport and East Croydon Railway Station,

KEYWORDS: Structure, Movement Joints, Animation, Video.

Introduction

The use of computer animation to move around and through buildings has become familiar in the last ten years. However, buildings are themselves in constant motion due to loading, settlement, thermal and moisture effects. These dynamic characteristics are critical in the determination of structural strategy in general and in the design of movement joints in particular. Because these movements are slow and small, they are rarely appreciated. However, some recent structures exploit these movements with more daring and, with the help of Computer animation to exaggerate and accelerate them, their effects on design can be appreciated far more graphically than before. This in turn leads to the possibility of better understanding and design of such features.

The first project analyses the elegant and intriguing structural solution applied in the recent refurbishment of Bracken House in London, and uses video techniques to demonstrate an alternative solution. The second two projects use animation techniques to illustrate the movement of structure, cladding and roofing components on specially designed jointing systems in Stansted Airport and East Croydon Railway Station.

The animations have been prepared using AUTOCAD AEC with transfer to 3-D STUDIO, or by the direct drawing of the building model and its animation within 3-D STUDIO. Animated output is then recorded on a standard VHS video system for final editing. The work by three undergraduate students [1,2,3] is acknowledged.

Bracken House

Bracken House was built for the Financial Times in 1959 but became redundant. In 1987, Michael Hopkins was commissioned to draw up proposals for its refurbishment. The structure is essentially a precast concrete frame but the animation sequence illustrates how the front four metres of the building is cantilevered out from the main structural frame, with beams of insufficient depth to support live loads and the façade. (Fig. 1) This is to provide sufficient space within the floor for the services but the cantilevered zone requires additional support. This is provided by a system of cast brackets at first floor level resting on stone (Fig. 2) and from which rise bronze columns giving the necessary restraint to the cantilevered beams, floor slab and façade at the upper levels. (Fig. 3) The video shows how these clamp on to the ends of the reduced section beam and onto the edge of the protruding slab to give the extra support required. (Fig. 4) The cast brackets being also cantilevered, are in turn themselves restrained from rotation by steel tensile rods anchored into the ground. (Fig. 5) An additional factor is that although the system would fail in a serious fire, it would do so long after the occupants had left the façade area.

An alternative and less complex solution would have been to allow the loadbearing stone masonry columns to run the full height of the building. (Fig. 6) The video sequence begins to illustrate the heavier visual effect of this alternative in comparison to the delicate and elegant façade (Fig. 7) achieved in the sophisticated solution adopted by Michael Hopkins. [4]

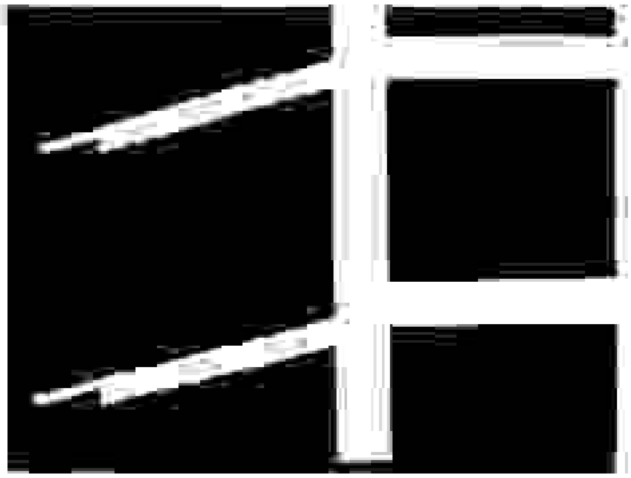


Fig. 1 Cantilever deflecting under full live loading

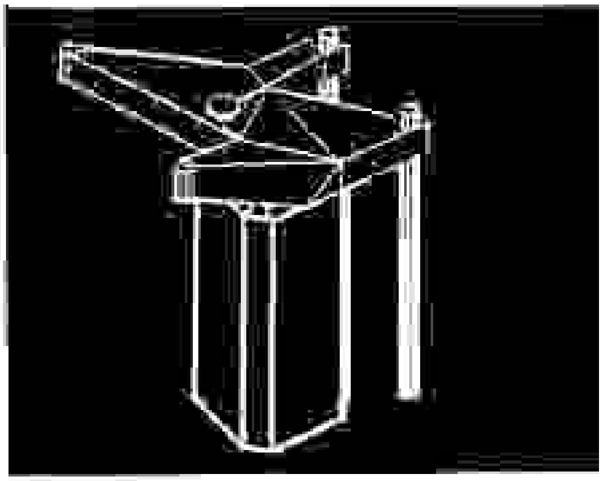


Fig. 2 Support bracket on stone columns

Fig. 3 Bronze support columns

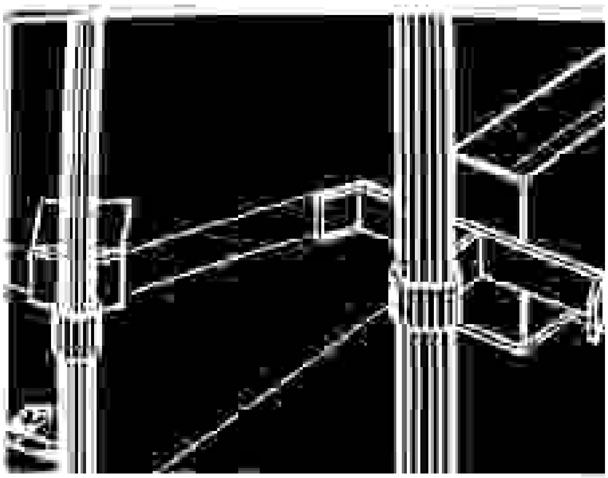


Fig. 4 Clamps to beam and floor

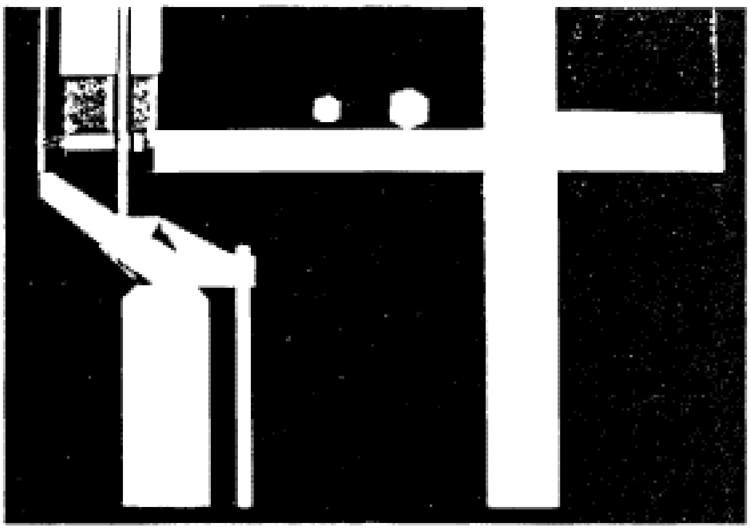
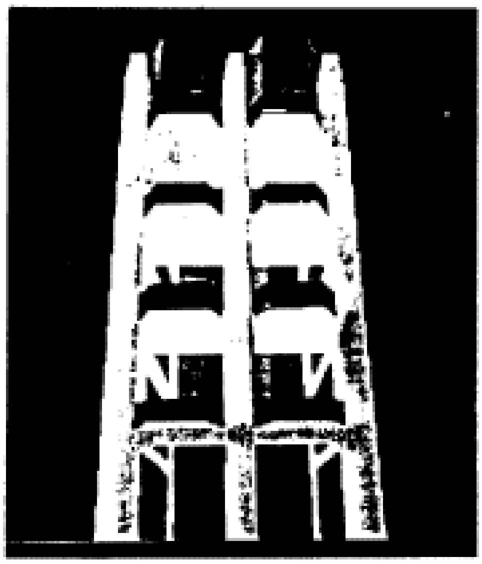


Fig. 5 Ground anchor to cantilever



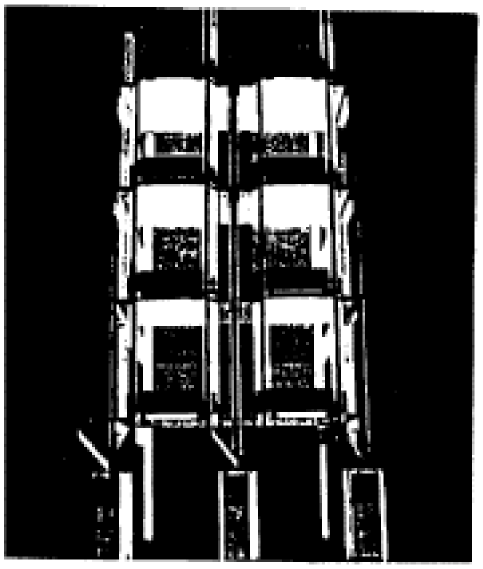


Fig. 6 Alternative masonry loadbearing columns

Fig. 7 Existing façade

Stansted Airport

Stansted Airport designed by Foster Associates [5] and completed in 1991, has a reinforced concrete undercroft surmounted by a structural steel concourse. The video/animation investigation of the movement joints focuses on the junction between the steel roof and the glazed façades of the concourse.
(Fig. 8)

The steel towers which are laterally restrained by the concourse concrete floor branch out to support the roof structure. (Fig. 9) The tree-like column with its restraining tension and compression members is sufficiently flexible to accommodate up to 100 mm of movement within the roof. By using a continuous roof structure and membrane over the whole space, the cumulative effects of thermal expansion can cause large horizontal and vertical movements at the perimeter. The video animation shows that under asymmetrical loading due to snow or wind pressure, (Fig. 10 & 11) the building tips towards one side and this too produces vertical movement in relation to the cladding.

The junction between the roof and cladding towards the corners of the building has to cope with translation of up to 80 mm in each of the three orthogonal directions. The animation shows graphically how the specially designed movement joint operates within three-dimensions. (Fig.12) Only such an animated sequence can show the full impact of its operation.

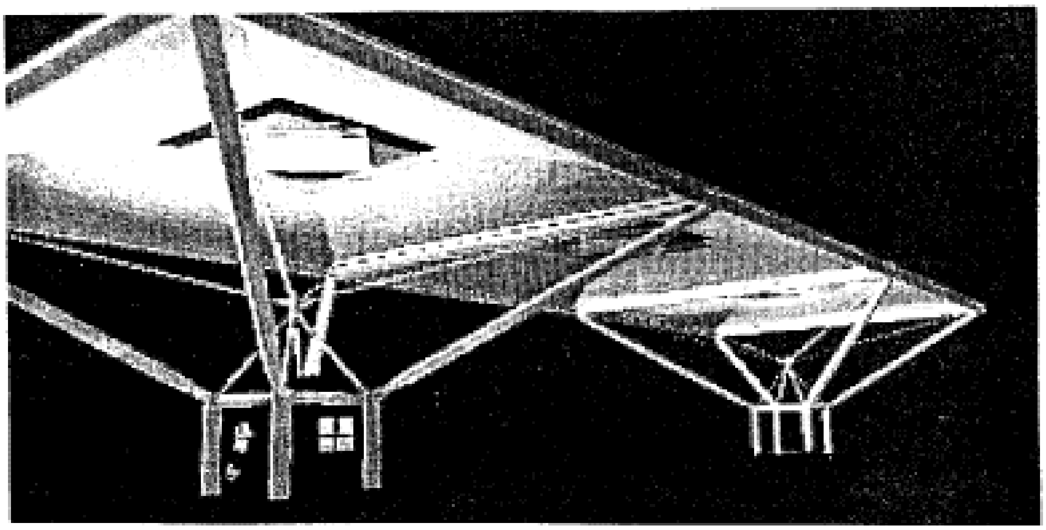


Fig. 8 Concourse structural system

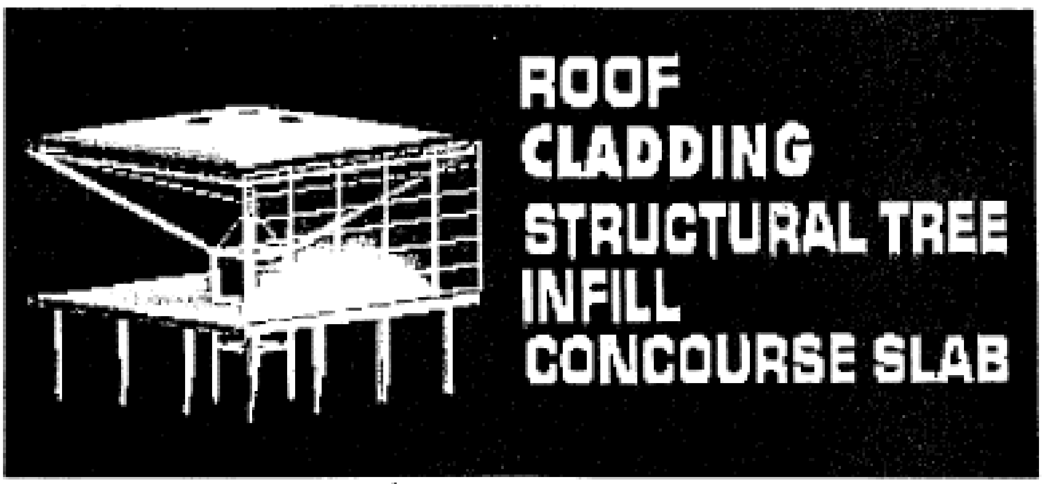


Fig. 9 Concrete concourse, steel structure and glazed cladding

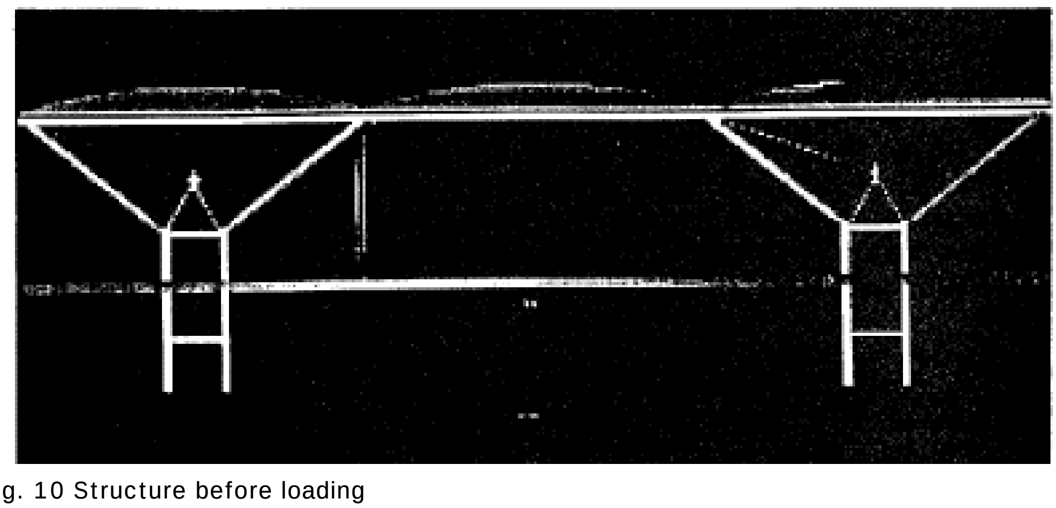


Fig. 10 Structure before loading

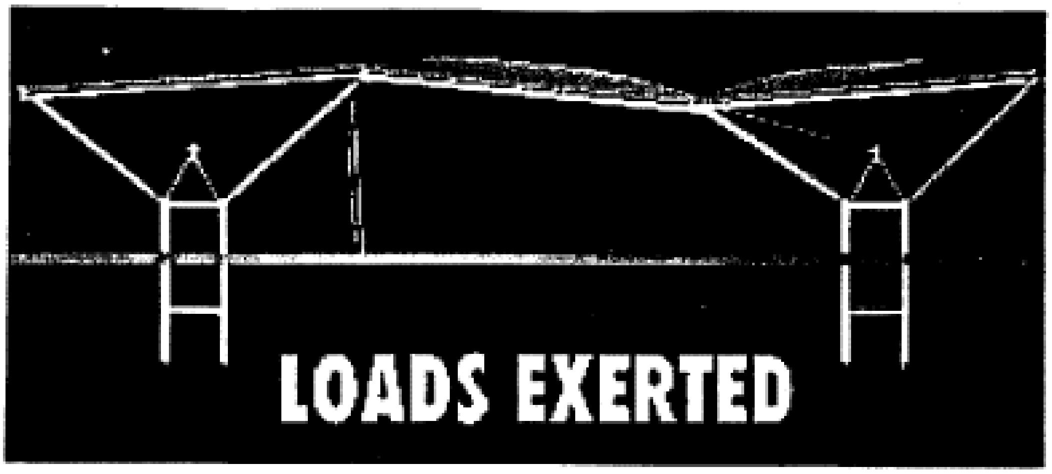


Fig. 11 Structure distorted by loading

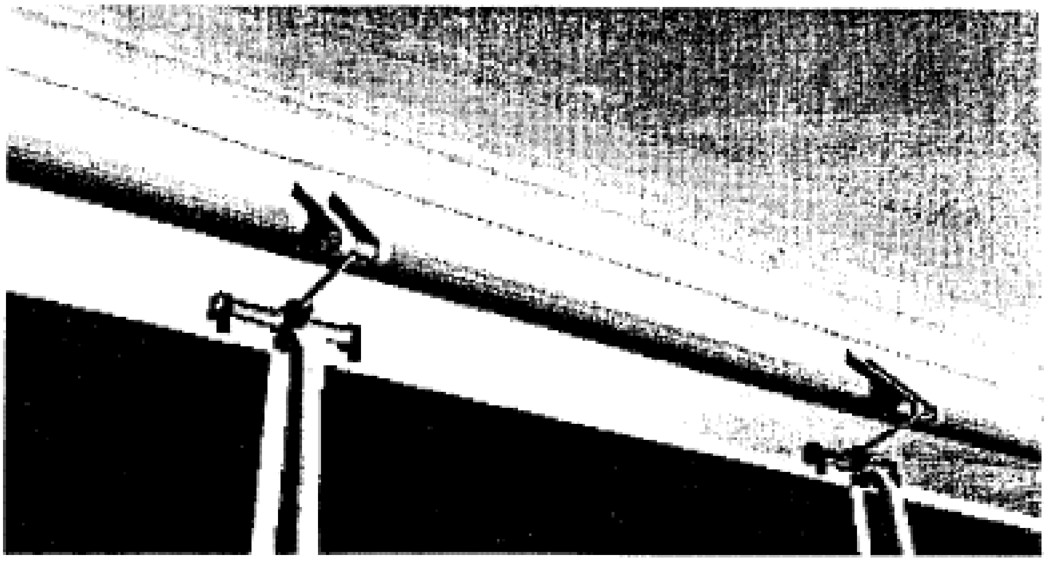


Fig. 12 Glazing to roof movement joint

East Croydon Railway Station

East Croydon Railway Station, designed by Alan Brookes Associates [6] and built in 1991, has a suspended steel roof spanning 55m. As with Stansted Airport, relative movement between the roof and glazing must be accommodated at the head and base of the glazing by ingenious mullion details. This must accommodate windload and suction on the elevations and thermal expansion and uplift on the roof. The video animation shows the effects of these movements.

The pin-joint at the mullion base allows for deflection from the vertical whilst a pin-jointed scissor arm connection, similar to that applied at Stansted, allows for both bending and vertical movement at the head of the mullion. (Fig. 13) The glazing is thus allowed to slide freely between two back to back angles retaining its seal against a rigid plastic coated silicone strip.

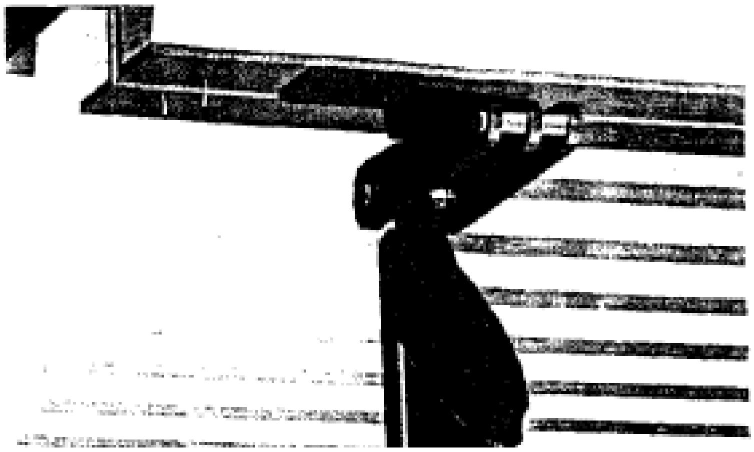


Fig. 13 Pin-jointed scissor arm joint

Conclusions

The dynamic analysis of existing buildings and of projected designs through their detailed modelling in CAAD systems and animation to explore their response to thermal movement and live loads, can lead to a greater appreciation of performance. As with all modelling, this should lead to greater creativity in the approach to structural strategy and design detailing. It moves architectural design dramatically into the fourth dimension.

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