CLADDING INTERFACE MANAGEMENT: UOB PLAZA, SINGAPORE

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SUMMARY

Problems in large scale complex buildings are more likely to occur at the interfaces between components or elements of the building. This is particularly true for elements such as high performance, bespoke designed cladding, and affects design development, construction and long term performance of the building. The key to improvements in the efficiency of building design and construction lies in the area of interface management.

UOB Plaza 2 was one of 15 case projects used to study interface management. This project was funded by the UK's Engineering and Physical Sciences Research Council (EPSRC). This paper presents the major findings regarding interface management and compares them with the findings from the UOB Plaza case study. The major findings are:

- Problems on complex construction projects become concentrated around the interfaces.
- Tolerance issues at the interface, particularly with the building structure, cause major problems.
- Different trades have different cultures, with different attitudes to tolerances, damage and interface responsibility.
- Proper interface consideration is essential for effective management of the design development, testing and construction phases. Failure will lead to poor coordination on site, contractual conflicts and future problems with the works.
- Effort invested at the early stages of the project, particularly early design development, will reduce the problems encountered later.
- A positive, proactive and open attitude to interfaces from the whole project team improves constructability and productivity on site.

KEYWORDS: Management, Cladding, Interfaces, Major Projects

INTRODUCTION

Problems for complex building projects are concentrated around the interfaces between components and elements of the building. The way that these interfaces are managed will affect the outcome of the project. The author has recently completed a two-year research programme funded by the UK's EPSRC and entitled "Testing Methods for Construction Interfaces." This programme forms part of the author's research into the interface management of large complex construction projects. This paper describes the research, concentrating on the design development of the external cladding elements of the UOB Plaza project in Singapore (Figure 1). The UOB project is compared with the results from the other case projects. Other facets of this research have been published elsewhere [1,2,3,4,5].

RESEARCH CONTEXT

Hypothesis of the research programme

The hypothesis of this research programme is that the key to improvements in the efficiency of building design and construction lies in the area of interface management. By concentrating on interfaces, weaknesses in design and construction should be identified, leading to improved standards of detailing and workmanship. In this context, the term 'interface' defines the junction between two or more elements or components of a building. There are, of course, relational and organisational interfaces that also need careful consideration, but these are outside the specific scope of this paper. This research centres on the design development and testing of high performance, bespoke cladding for major building projects, as this is one of the more complex aspects of

construction.

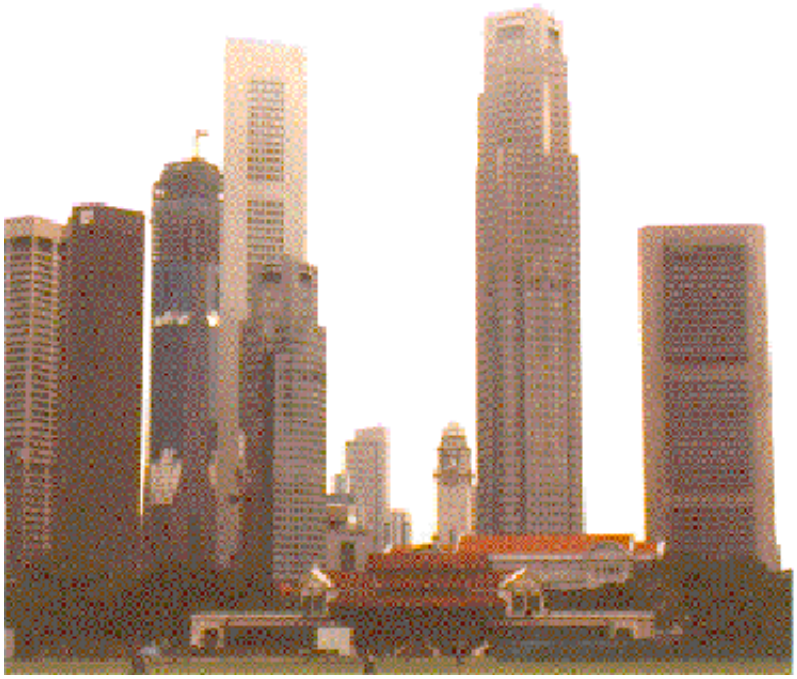

Figure 1 Singapore financial district skyline with UOB Plaza 1 right of centre and Plaza 2 left of centre foreground

Research methodology

Case studies of 15 construction projects listed below were completed by:

- interviewing key project personnel
- visiting the site and cladding works
- witnessing prototype tests
- obtaining project documentation

1	Camomile Street, London	2	ICC, Edinburgh	3	Embankment Place, London
4	Compass Centre, Heathrow	5	IFF, New York	6	10 Ludgate Place, London
7	100 Ludgate Hill, London	8	100 New Bridge St, London	9	Inland Revenue, Nottingham
10	Stockley B8, London	11	Stockley B9-12, London	12	Stockley W3, London
13	UOB Plaza, Singapore	14	Vintners Place, London	15	MAFF, York

The 13 UK cases were chosen to reflect the spectrum of complex cladding projects. The 2 non-UK cases represent the most common type of complex cladding projects in those localities. All 15 projects involved complex external cladding of bespoke design which required project-specific testing. 59 key project personnel were interviewed from the following types of organisations:

- Client or Client's Project Manager (5)
- Architect (17)
- Independent Test House (4)
- Cladding Consultant (7)
- Specialist Cladding Contractor (14)
- Major Contractor (12)

In addition, the views of others involved in the cladding design development and testing process were obtained through postal

questionnaires and structured discussions. The author acknowledges the significant contribution to the research programme by senior personnel from the case study projects and other contributors.

Key interfaces on case study projects

The research identified the key interfaces that occurred on the case study projects. These are shown in Figure 2. The interfaces are defined as major and minor interfaces. For example, on all projects there was some interface between the cladding and the building services, which was often relatively straight forward. The relative importance of these interfaces is outside the scope of this paper and has been discussed elsewhere by the author. [1,5]

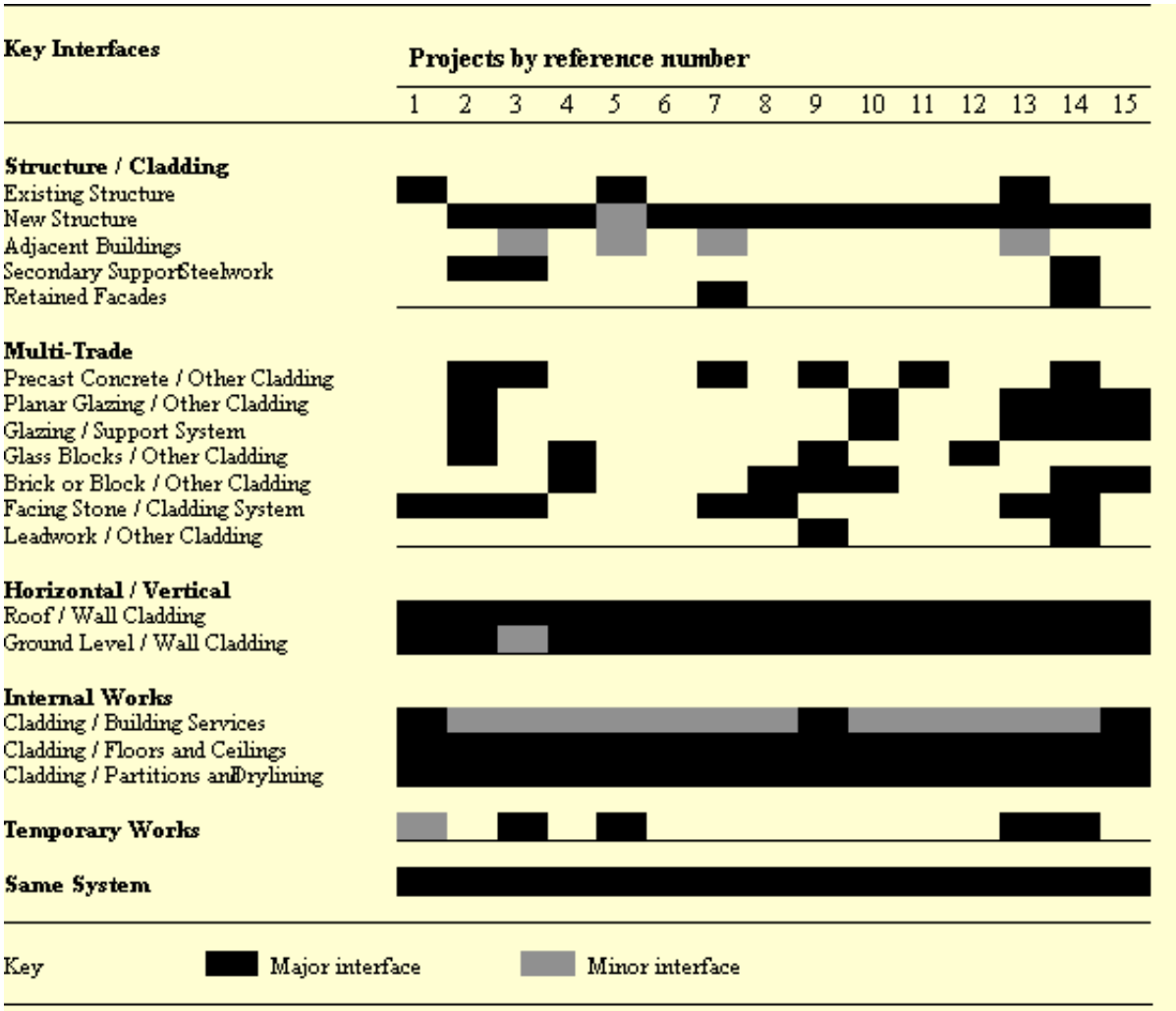

Figure 2 Key interfaces on case study projects

Research Conclusions

The following are the key conclusions from the study:

- Problems on complex construction projects become concentrated around the interfaces.
- Tolerance issues at the interface, particularly with the building structure, cause major problems.
- Different trades have different cultures, with different attitudes to tolerances, damage and interface responsibility.
- Proper interface consideration is essential for effective management of the design development, testing and construction phases. Failure will lead to poor coordination on site, contractual conflicts and future problems with the works.
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THE UOB PLAZA 2 PROJECT, SINGAPORE

UOB Plaza 2 Project Description

The UOB Plaza Development comprises two granite clad high-rise office towers, hexagonal in plan, in the centre of Singapore's financial district (Figure 1). The Client and primary occupier of the development is the United Overseas Bank (UOB). The two towers are 66 and 48 stories high, the larger (Plaza 1) being a new-build structure and the smaller (Plaza 2) a major refurbishment of a 44 storey block initially constructed in the 1970s. The two towers are linked at the lower level by a podium building, incorporating a large public area, banking halls and reception areas.

Plaza 2, the main focus of this paper, cost around S$ 95 million (£43 million) and was completed in 1995. It was a traditional, lump sum contract but with significant variations and several nominated subcontractors. The top section of the building, which incorporated a large plantroom area was completely removed and three new floors and a new plantroom were added. The rest of the building was stripped back to the structural frame and re-fitted. The original cladding was precast concrete with aluminium windows, which was completely removed and replaced with a granite-clad, metal and glass curtain wall to match Plaza 1. There is a large glazed canopy over the entrance area.

UOB project team and interviewees

The following key project personnel were interviewed:

- Lau Guan Ho, General Manager / Director of Client UOB Property Management (UOB)
- Lim Chow Weng, Project Architect with Architect 61 who were responsible for the detail design development of the project from a scope design by Japanese Architect Kenzo Tange.
- John Perry, Head of cladding consultant Arup Facade Engineering, Australia (AFE)
- David Dines, Project Manager with joint venture contractor Wimpey Woh Hup (WWH)
- Y Y Cheung, Project Designer of main cladding package contractor Permasteelisa Pacific Pte Ltd (Permasteelisa)
- John Byrne, Project Manager of canopy cladding package contractor Grill and Grossmann (GIG)

Plaza 2 cladding elements

Main wall cladding

The main wall cladding is a granite-clad, metal and glass curtain wall, comprising an aluminium sub frame with insulated metal panel as the weather wall behind the granite which acts as rainscreen. The Plaza 2 unit statistics are as follows:

- ~3500 units covering ~20 000m2
- Standard module 3.65m high x 1.85 wide
- Average weight ~ 550kg
- Value of cladding package S$ 21 million (£9.6 million)

Glazed Entrance Canopy

Plaza 2 includes a 26.3 x 36.3m glazed entrance canopy cantilevering out from the main building (Figure 3). The value of the canopy glazing package was S$ 3.5 million (~£ 1.6 million) The canopy design was developed in Austria by Grill and Grossmann (GIG). The canopy structure is a series of fully welded, tubular stainless steel trusses. The trusses were fabricated in Austria, but the longer sections could not be shipped, so were welded on site.

Figure 3 Inverted glazed canopy to plaza 2 - main structural hanger shown at the top centre

The glazing used was the Tempoint system from Ashai Glass, Japan. This is a similar system to Pilkington's Planar. The Planar system has been used in the UK in an inverted roofing condition (i.e. where the support is above the glazing) on projects such as Vintners Place and East Croydon Railway Station. However, this is the first time that the Tempoint system has been used horizontally. The system supports the glass panels at a number of node points. The node fixings are a highly engineered, bespoke design. There is a chamfered hole in the glass through which a stainless steel bolt with a chamfered washer connects the glass to the node fixing.

Roof Plant Room Cladding

This comprised cold-rolled purlins fixed to main steel frame by UGO of Singapore, with profiled metal cladding supplied by Stramit.

KEY INTERFACES ON PLAZA 2

Significance of construction interfaces

The significance of construction interfaces was one of the main findings of the overall research project. UOB's Lau (who has authored a book on project management [6]) agrees, commenting that there are interface problems, not just on cladding, but with air conditioning, electrics, ceiling finishes. Lau's philosophy is that you should get rid of your problems by solving them early, rather than letting them hit you on site - "If you try to solve them on site then you are likely to create other problems - I think you should try to resolve the things in design then when you come to site there will be less problems - you can not solve everything for a big project, but you must try."

Main wall cladding interfaces

Main cladding interface with the building structure

The original building structure was quite badly twisted by around 100mm. This twist had to be built into the fixings for the wall cladding. After the demolition of original cladding the existing frame was surveyed and cladding contractor Permasteelisa then designed the fixings to suit. Lim claims that the design was easy in that they allowed for a 230mm zone, but the problems came in construction against an existing structure. He added that "the problems don't go away - you just need to face them".

The fixings changed where there are different conditions (e.g. steel or concrete, different edge distances etc.). Nevertheless, on

many floors there was still a lot of repetition. The fixing was basically an angle bracket bolted and grouted to the slab edge, cantilevering out to pick up the individual panel fixings, with a shear plate on top to accommodate the horizontal wind load.

WWH's Dines commented that "deflections never seem to go to plan". On Plaza 2 there was a large provision for movement - basically the settlement of the umbrella truss. WWH had to try to obtain maximum dead load conditions, by loading up the upper floors with sand and cement, before the cladding was fixed to try and make the structure deflect the projected 25 to 50mm. However, the deflection did not occur and this caused problems at the set backs at high level, where the cill member was slotted to accept the cladding above.

Main cladding interface with internal wall linings

Once the cladding was installed the internal wall lining was fixed by a WWH domestic subcontractor, terminating at an angle on the cladding fixed by Permasteelisa. This interface allowed for minor movement at this junction. Lim stated that there were some problems with the twist in the structure causing some of the linings to be considerably out of line with the cladding opening, resulting in the need for some *dog-leg* rebates in the reveals.

Main cladding interface with floors and ceilings

Plaza 2 had a 20mm nominal floor screed rather than a raised floor. Therefore the floor and ceiling interface was more critical in terms of level. First the blind boxes and window surrounds were installed thus determining the line of the internal dry wall and ceiling. The suspended ceiling followed around, connected onto the blind box and the column. Dines stated that there were no problems with the levels despite the tight spatial constraints.

Main cladding interface with louvres

These were done by the cladding contractor anyway and therefore this was not a contentious interface. WWH's domestic subcontractor had to achieve a jamb, head, cill detail on the cladding to make it watertight. Then the air handling ductwork was connected onto Permasteelisa's architectural louvres.

Secondary steelwork to main cladding

On most complex, bespoke designed projects secondary steelwork is required to accommodate the facade. Typically, this is not designed by the main structural designer as precise details are not known at the time of the main structural design. On Plaza 2 this steelwork was left to WWH to coordinate although it had been priced provisionally as part of the main steel package (NKK - Japan). Permasteelisa issued information to NKK via WWH and details were then approved by the main designer Ove Arup. WWH then had to resolve any interface or coordination problems.

Glazed canopy interfaces

Fixing the brackets to the structure through the curtain wall

Canopy contractor GIG stated that this was their main critical interface. The canopy support was fixed through the cladding to the main structure via a galvanised steel bracket. The detail was developed following site measurement after the removal of the existing cladding. GIG removed the fire protection and set out the main canopy trusses to gridlines and datums thus establishing the height of the Permasteelisa stonework. Once the GIG brackets were in they had to wait for the Permasteelisa panels to be put in before they installed their trusses, followed by the infill stonework by Permasteelisa. Byrne explained that the drawing showed a clearance of 15mm around the brackets through the cladding, but it ended up around 25-30mm. This joint was then siliconed by Permasteelisa as it was their responsibility. The main raking tie connection at level 8 was designed by Ove Arup (Figure 3). The galvanised steel strap goes round the perimeter column then back to the core at floor level with a steel plate going up the face of the core to ensure that the load is adequately distributed.

Canopy gutter interface

There was a gap left at the bottom of the cladding for GIG to install a stainless steel gutter for the canopy, then underneath the gutter Permasteelisa installed a flashing piece. Lim explained that the main issue here was the setting out, how to sort out a common line and level. In addition, watertightness, especially at the gutter, was a key consideration as there was a lot of water in that location. He stated that typically the principle was for one party to be responsible for the water tightness - usually the curtain wall contractor - therefore the flashing and weathering was by Permasteelisa.

Canopy electrical interface

WWH's domestic electrical subcontractor had to route cables from the building, though the trusses via conduit, to lights under the canopy. GIG met with the electrical subcontractor to agree the conduit routes. GIG felt that it was better to do the conduit work offsite before it was fabricated due to access problems once the trusses were installed. GIG put draw wires in then the electrical subcontractor pulled the wires afterwards.

Interface with plantroom cladding at roof level

The high level *Stramit* metal cladding around plantroom areas is very much independent from the main wall cladding. There is a two stage weather seal with a stepped flashing at the top which steps over the curtain wall and then a cosmetic stainless steel coping was installed. All the work was completed by Permasteelisa including the final flashing with the *Stramit* cladding just tucked in afterwards. This is a good example of a subsequent interface (4) where the different trades are separated such that only one handover between them is required, rather than an iterative interface requiring a series of iterative and inter-dependant operations by each trade.

Interface with the stepped roofs at high level

There are a series of flat roof step backs at the upper levels of the building as the floor plate reduces in area. These were euphemistically named *planter boxes* by some of the project team. Lim explained that the detail always follows the same principle with Permasteelisa doing the flashing, but the water proofing to the roof by the main contractor. Lim and Dines accepted that some problems were encountered both with design development changes of the cladding interface and the structural deflection issues discussed earlier. Permasteelisa added that in some cases remedial works were required to the concrete upstands after the main wall cladding had been fixed. The project team accepted that sometimes the pressure of progressing the works at the expense of obtaining the correct interface detail becomes a commercial reality. Notwithstanding, appropriate remedial works were completed and the detail amended.

INTERFACE MANAGEMENT ON PLAZA 2

Design development

Most of the organisations appointed one individual to coordinate the design development and to ensure that the interfaces were properly considered.

The interviewees were asked how the concept design was worked up to the detail stage, particularly at the interfaces. UOB's Lau clearly believed in the benefit of face to face discussion. "I sit them down and get them to talk. Lau's perception of design development is straight forward: "The concept architect says what he wants - Arup do their bit - the subcontractor does the detailed design - Arup and A61 check the details - the subcontractor produces the work.

Lim stated that interfaces were developed at face-to-face meetings with the combined subcontractors - 2 or 3 trades at one time. These were very intensive meetings, at least once a week, and they spent quite a lot of time sorting out the details, in theory at least. Cheung cites an interface detail that changed through design development, namely the cast-in fixing brackets were shown in early tests to cause concrete to crack at the slab edge. The solution was to weld an additional reinforcement 'U' bar to the channel bracket.

Byrne explained that the tender drawings indicated the scope of the works and although there were a few changes to this information it formed the basis for design development. GIG were also given a survey of the existing structure but they supplemented this with their own as they were contractually responsible for ensuring that the works would fit on site. He explained that it was clear that anything to do with the stainless steel or glass in the canopy area was ours - they were given the complete design package. The project team had already chosen the *Ashai* system and provided GIG with the external dimensions of the truss members. GIG then varied the tube thicknesses to cope with the design loads, and in some cases installed sleeves within the tubes to increase their stiffness.

Meetings

The interviewees were asked to describe how the various parties involved met with each other during the project. The emphasis here was meetings between interfacing specialist contractors rather than just between one subcontractor and the main contractor.

There were weekly design coordination meetings with the architect and both GIG and Permasteelisa. Byrne stated that they were given a time to arrive and have their own individual meeting - then Permasteelisa would come in - and the first questions

Permasteelisa would ask were about the canopy area and interfaces with GIG. Byrne explained that there was little need for them to initiate meetings as there were enough formal meetings anyway. Byrne stressed that it was agreed at the start of the project that anything GIG agreed with Permasteelisa was not agreed because the main contractor did not know about it. This tended to dissuade the practice of ad hoc meetings between specialists.

Byrne explained that, in Singapore, it is common for the client to get more involved and ask to see the specialist contractor informally. Byrne stressed that he would always invite the main contractor to attend these meetings. It appears that in Singapore, company directors only get involved in the projects if there is trouble. Also, with the exception of a *topping out* ceremony meetings convened for social purposes were not part of the UOB strategy.

The interviewees identified key issues to ensure meeting effectiveness as: a clear agenda and objectives; a required performance; good time keeping; keeping to the point; developing and maintaining a positive attitude - problem solving not fault finding.

Drawing management

Including full interface details on subcontractor's drawings

Permasteelisa's Cheung believes that drawings are key to sorting interfaces. Their approach is to draw complex interfaces in detail and sometimes add specific detailed method statements on the drawings. Byrne acknowledged that on some of the gutter details GIG included Permasteelisa's cladding works and the flashing, to assist in working out the interface.

Distribution of drawings between interfacing subcontractors

Byrne explained that there was a specific method required for drawing submittal etc. The official line was that Permasteelisa and GIG would issue six drawings of everything to WWH who then distributed them. However, both Cheung and Byrne explained that to expedite the design development, because there were regular meetings, and out of courtesy they would issue one copy direct to one another. Byrne recalls that WWH's view was that as long as they were kept informed then they were comfortable with this arrangement. Where necessary this action would be agreed at the meetings.

Free supply items issued to interfacing subcontractors

Dines explained that there were no *free supply* items issued to interfacing subcontractors on Plaza 2. For example the main cladding all brackets were supplied <u>and</u> fixed by Permasteelisa - including welding to steel beams.

Fixing into or between cladding systems

Because of the complex nature of cladding elements on large buildings there is often the need to fix items onto the cladding, or connect two different systems together. This practice can create problems with responsibilities and warranties at the interface. GIG's Byrne stated that even for the canopy trusses they were fixing back to the structural steelwork, through the main cladding - their works did not connect to the cladding, or even touch it. Permasteelisa then sealed around the slot between the bracket and the cladding. Cheung described the internal *gyproc* wall linings which were supported by an independent metal stud system. The over-riding principle was that fixings were not allowed into the cladding mullions.

Specific performance testing of construction interfaces

The research project investigated testing methods for construction interfaces. On UOB there were a number of performance tests on the building facade, in line with contemporary good practice for high rise buildings. Tests cost about S$ 200 000 - 300 000 (UK £ 91K - 140K)**.** The mock-up sample for Plaza 1 was tested in Australia and included a corner section which is one of the key *in system* interfaces. Lim explained that they "wanted a section that represented the typical situation, inclusive of the window and interfacing with the floor. It should be large enough to include all relevant aspects such as a corner. The flooring was represented by steelwork, but the actual brackets were used." However, there were no intra-trade interface tests on UOB, Cheung believes that they were such a small amount compared with the 66 stories - therefore they were not considered significant.

Lim stated that UOB is a difficult building to go back and do remedials because of high-level access. This realisation supports the need for effective cladding testing. Client Lau claimed that he would support similar tests on future jobs adding that although every job will be different, it is the edges and corners that cause the problems not the main panels. He believes that you can calculate out lots of things, but if you test then at least you know that before you installed it then it was okay, rather than to put it up and then find that there are problems.

CONCLUDING REMARKS

The UOB Plaza team supports the view that problems are concentrated around interfaces, and effective interface management is a necessary ingredient for successful project management. They adopted an interface management strategy throughout the design development stage which included individual responsibility, face-to-face meetings, drawing management, fixing restrictions and appropriate performance testing.

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