ARTICLE

Perceptions of Precast Concrete Cladding in the UK Market

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Abstract

Precast concrete cladding accounts for about 5% of the UK cladding market, despite its performance and aesthetic advantages over competitor materials. A study of perceptions of precast concrete cladding (PCC) was undertaken with the aim of assessing awareness and use of PCC in the UK in its most popular applications (i.e. commercial and residential buildings), in addition to identifying possible directions for future research and development. Interviews were undertaken with participants who were familiar with PCC (predominantly on commercial buildings) and who had had experience of stone-faced, reconstituted stone, cast stone and brick-faced precast cladding. The interviewees identified major opportunities/impelling factors thought to encourage the use of PCC and major barriers/impeding factors thought to discourage its use. A simple scoring system was used to combine the number of responses for each factor with the relative importance assigned to each response. 'Buildability', 'quality' and 'speed of erection' were the most highly rated impelling factors whereas 'lead time', 'initial cost' and 'logistics and cranage' were the most highly rated impeding factors. Developments in production techniques, finishes and sustainability performance together with the need for improved marketing of the product were identified by interviewees as key activities to improve PCC's share of the UK cladding market.

■ *Keywords* – Building design; cladding; façades; precast concrete; interfaces

INTRODUCTION

Precast concrete cladding (PCC) panels are large, often storey-height panels, produced off-site in factories, utilizing high-quality finishing techniques to suit the needs of the bespoke architectural cladding market. The popularity and hence market share of precast concrete cladding has varied significantly over time and its current share of the UK market for wall cladding is estimated to be, at most, 5%. A study of perceptions of PCC was undertaken with the aim of gauging awareness and use of PCC in the UK in its most popular applications (i.e. commercial and residential buildings) and to identify generic factors affecting its take-up in those markets. A series of interviews was undertaken to identify the major opportunities thought to encourage the use of PCC, the major barriers thought to discourage its use and possible directions for future research and development (R&D). This paper presents an overview of previous related research, summarizes results of the interviews and makes a number of recommendations aimed at helping the PCC industry to increase its share of the UK cladding market.

THE MARKET FOR PCC

The production of large concrete façade cladding panels off-site in a factory environment is referred to as precast concrete cladding. Panels can be made virtually any shape or size, but storey-height panels are typical as they are transported to site easily by road, can be erected quickly onto a concrete or steel structural frame and have fewer joints than smaller panels (Richardson, 1991; FIP, 1994). PCC panels are usually non-loadbearing, supported from the base and restrained at

the top; a storey-height panel (4 m high × 3 m wide) would be approximately 150 mm to 180 mm thick, not including insulation and/or dry lining (Dawson, 2003). A range of finishes can be provided (by manipulating the cement, aggregate and pigment types, sizes and/or proportions), in addition to profiles, mouldings and rebates, etc. Taylor (1992), FIP (1994) and Freedman (2001) explain a number of finishing techniques from plain, acid-etched finishes to rough, grit-blasted surfaces; Gibb and Brand (1996) and Dawson (2003) describe developments in brick, terracotta and stone facings.

The origins of PCC lie in the production of cast stone in the late 1800s, but Morris (1966) explains that PCC has been used throughout the UK since around the 1950s for residential, commercial and other applications, although examples can be found in earlier Modernist buildings, according to Dawson (2003). In her analysis of the history of precast concrete in housing, Glass (2000a) notes that the demand for off-site panels grew significantly in the 1960s as 'system building' types of construction grew in popularity. She explains that the Ronan Point disaster in London in 1967 and other well publicized, but less dramatic, failures had the effect of severely blighting the product until the late 1980s when an economic boom and preference for Post-modernist architecture improved its fortunes.

During the intervening period, the market slowed again and technical façade engineering solutions (e.g. glass, metals and terracotta rainscreen systems) grew in popularity. Confidential market reports indicate that PCC now commands only about 5% of the 30 million m^2 market for cladding products in the UK. Other published sources put this figure at around 2%, with metal products accounting for over 70% of the market (MBD, 2004). Precasters from mainland Europe (notably the Netherlands and Belgium) have recognized the UK market's potential and have won several prestigious projects (e.g. in London, Birmingham and Sheffield), thereby putting competitive pressure on UK PCC manufacturers. These market pressures have been compounded by the Aggregates Tax (cf The Aggregates Levy Regulations, Statutory Instrument 2002), which increased the unit cost of all concrete products made in the UK compared with other European Community (EC) countries. Given this situation, it was apparent that the share and stability of the market for PCC was under threat and research was needed on reasons for specification (or non-specification) of the product.

Previous work by Glass (2000b) on tilt-up concrete panel construction suggested that the major barriers to exposed concrete finishes on building façades were often based on perceptions and personal aesthetic preferences, rather than actual experience. Indeed, there is a growing body of research on decision-making processes in construction projects. For example, Idrus and Newman (2002) developed a cost and time model for decision-making in relation to concrete frame structures and recent research has acknowledged the heuristic, often unstructured, nature of decision-making, for example, Ballal and Sher (2003) and Barrett (2003).

On a more pragmatic note, Soetanto *et al* (2004) propose a decision-support tool to enable teams to select an appropriate structural frame using both 'hard' (cost and time) and 'soft' criteria, such as appearance and layout. This transparent and rational approach may be particularly appropriate for cladding projects. Ledbetter (2003) explains that for such projects: 'the decision making process can easily be debased and become dysfunctional'. Such potential complexity in the process was echoed in Walker (2004) who explains that the precast concrete cladding supplier can act as a specialist contractor, using a broad skills base to provide design, manufacturing, haulage and, in some cases, construction (or erection) services.

In the UK, Glass (2005) investigated a number of completed buildings that had used precast concrete as part of the structure and/or cladding: the selection of precast concrete was found to be dependent on the client having confidence in the solution and there being an atmosphere of trust within the team. In most cases, she found that the design team had to provide evidence to demonstrate the value of the precast option to the client. This was one of the major findings to be incorporated in best practice guidance on precast and in-situ combinations (Goodchild and Glass, 2004).

A review of the PCC industry in Belgium reported by Naert *et al* (2002) identified the main barriers to PCC as aesthetics, quality of finish, cost, ease and speed of construction, but noted that a national marketing campaign had produced a significant increase in market

share from 35% in 1990 to 50% in 1998. Activities focused on promoting the aesthetic possibilities of PCC to around 10,000 practising architects, architectural students and others (e.g. civil servants and engineers), via a range of highly targeted publications, lectures, the Internet and television advertisements. The UK PCC manufacturing community was aware of the impact of the Belgian programme and, given the market pressures described above, supported a short study to investigate current market perceptions of PCC with a view to informing its own R&D and marketing strategy.

RESEARCH METHODOLOGY

The combination of market pressures and a lack of specific, recent research on PCC in the literature supported the need for an urgent, but meaningful study to research the awareness and use of PCC in the UK in its most popular applications (i.e. commercial and residential buildings) and to identify generic factors affecting its take-up, under two headings:

- opportunities that could be capitalized upon to stimulate growth in demand
- barriers that should be overcome to prevent any further decline in demand.

Personal interviews were selected as an appropriate method to capture detailed experiential information. A simple, easy-to-administer and fast-to-analyse semi-structured interview format was developed using a proforma suitable for use in both directed personal and telephone interviews, based on conventional techniques described in Bryman (2001). It was designed to allow self-completion by informants if necessary. The questions included closed, open-ended and self-assessment styles. The draft interview agenda was compiled based on the literature and included core questions on opportunities for PCC and barriers constraining its use. In addition, contextual questions were added to establish experience, company size, as well as interviewees' awareness, responsibility for, and use of particular PCC products or techniques (e.g. stone-faced or brick-faced panels, etc). To obtain a simple indication of the most popular applications for PCC, a further question asked respondents to relate which PCC products had been used for particular building functions (e.g. commercial, residential, etc.).

The proforma was used in a pilot face-to-face interview on an experienced architect and sent out for comment to two structural/civil engineers. It was amended slightly as a result, mainly because feedback from this exercise suggested that a series of discursive probes be added to capture practitioners' broader views on PCC. The probes covered levels of satisfaction with PCC, what manufacturers could do to improve the product or service they offer, future directions for R&D, what practitioners need to know in order to use PCC more effectively and the future market potential for the product.

Interviewees were selected using a purposive sample of experienced, knowledgeable practitioners from the key professional and trade (PT) groups associated with cladding specification, design and construction; this was based on methods reported in Glass and Baiche (2001). At least two interviewees were chosen from each of the following PT groups: architects, structural engineers, clients, quantity surveyors/clients' agents and project/construction managers. A list of 36 possible candidates was drawn up by identifying industrialists who were known to have sufficient industry experience and expertise to express views on the use of PCC (e.g. evidenced anecdotally to peers in the industry, from experience of completed projects or cladding packages, via contact with precast cladding manufacturers, or in the trade press). Of these, 11 people agreed to personal interviews, two more completed telephone interviews and two people completed a written version of the questionnaire.

Having e-mailed or mailed the interview agenda to each participant, the researcher visited the premises of interviewees who had agreed to a face-to-face interview with each session lasting between 45 minutes and two hours. The researcher was knowledgeable in the subject matter and so was able to play an active role in each interview, asking for clarification and using probes as appropriate to obtain fulsome responses. During the visits, the researcher noted responses to closed (scoring) questions on a pre-prepared sheet for scoring or ranking later. The interviews were recorded on a voice recorder so that responses to questions of a discursive nature could be transcribed in full and entered in a tabular format for analysis.

The priority for the interviews was to gain qualitative, expert information: the methodology was not designed to produce extensive quantitative analysis. However, some simple analysis was undertaken to prioritize the key issues on the premise that a larger scale questionnaire survey was to be undertaken thereafter (to include comparison with other cladding materials). The results of the interviews are presented below, followed by a discussion of their implications and conclusions.

RESULTS AND ANALYSIS

INTERVIEWEES AND THEIR ROLES

The participants were categorized by their professional/trade (PT) groups (see Table 1); in some instances, two PT group notations were used (e.g. an individual in a consulting engineering firm with particular responsibility for façade engineering is denoted CE/FE). The interviewees had between seven and 40 years' experience in construction; 10 had at least 20 years' experience. A broad range of company sizes was represented, from 12 to 3,000 employees; eight of the companies were small and medium-sized enterprises. In terms of annual turnover, there was a broad spread from less than £1m to more than £500m.

The participants were asked to self-assess their role in the decision-making process on a Likert scale from 1 to 5, where 1 = Not responsible to 5 = Solely responsible; the responses are shown in Table 2. At least four different PT groups considered that they exerted 'major influence' over cladding specification, design, manufacture and construction processes, i.e. architect, client, consulting engineer and main contractor. Practitioners with particular responsibility for façade engineering consistently identified themselves as having 'major influence', but no individuals regarded themselves as 'solely responsible', confirming Ledbetter's analysis (2003) in which a typical cladding supply chain is described as deep and complex. The fact that professional/trade group responses cannot be grouped consistently in Table 2 may be a result of the small sample or possibly the varying levels of experience within the participants.

TABLE 1 Interviewees: notation used for professional/trade groups (multiples are indicated in brackets)

P/T NOTATION FOR THE 15 INTERVIEWEES	
AR (x 4) CE CL (x 3) CM/PM FE/CE FE/MC MC QS/PM (x 3)	
AR	Architect
CE	Engineer/consulting engineer
CL	Client and/or developer
CM	Construction manager
FE	Façade engineer
MC	Main contractor
PM	Project manager
QS	Quantity surveyor

AWARENESS OF AVAILABLE PCC OPTIONS

The participants were asked to indicate their awareness and familiarity with a range of typical PCC products and finishes. A list of possible options was compiled from literature, namely Taylor (1992) and Dawson (2003); this is shown with the informants' responses in Table 3.

PCC products/finishes used by at least half of the participants were as follows: brick-faced, cast stone, reconstituted stone and stone-faced panels (ashlar). The scores recorded in this question indicate that the majority of interviewees were aware of the various options, but votes cast were split almost equally between those who had used (82) and those who had not used (84) the products stated. A number of interviewees were not clear about the terminologies (e.g. cast stone, reconstructed stone, reconstituted stone, stone-faced, etc.), so no further analysis was carried out. Suffice to say, guidance is required on definitions, which confirms concerns cited in Arditi *et al* (2000) regarding the need for better coverage of precast concrete in the educational curriculum.

USES FOR PCC PRODUCTS

Participants were asked to identify building types on which they had used PCC products; the responses are shown in Table 4.

The vast majority of responses were recorded in the 'commercial/offices' category (63 votes cast) for which at least half the respondents had used brick-faced, cast stone, exposed aggregate, reconstructed stone and stone-faced panels (ashlar). This is in line with the balance of case studies featured in Dawson (2003), in which more than half were commercial/office projects in the UK.

PCC lends itself to large, framed structures that allow the precaster to maximize repetition and unit size while providing high-quality, often stone-faced finishes selected on the basis of their giving *gravitas* to a

TABLE 2 Interviewees' roles and responsibilities in the PCC decision-making process

	1 NOT RESPONSIBLE	2 SOME INFLUENCE	3 MEDIUM INFLUENCE	4 MAJOR INFLUENCE	5 SOLELY RESPONSIBLE
Select – decision to use	CE	AR	CL	AR	No responses were recorded in this column.
			CM/PM	AR	
			QS/PM	AR	
			QS/PM	CE/FE	
			QS	CL	
				CL	
				MC/FE	
				MC	
Design and specification		CM/PM	AR	AR	
		QS/PM	AR	AR	
		QS	CE	CE/FE	
			CL	CL	
			CL	MC/FE	
			QS/PM	MC	
Manufacture and construction	AR	CL	AR	AR	
	CL	QS/PM	AR	CE/FE	
		QS/PM	CE	CM/PM	
		QS	CL	MC/FE	
				MC	
Total (by level of influence)	**3**	**7**	**15**	**19**	

TABLE 3 Awareness of, and familiarity with, a range of PCC products (votes cast by the 15 respondents)

	NOT AWARE OF IT AND HAVE NOT USED	AWARE OF IT, BUT HAVE NOT USED	AWARE OF IT AND HAVE USED OCCASIONALLY	AWARE OF IT AND HAVE USED FREQUENTLY
Brick faced		5	**10**	
Cast stone		4	**11**	
Exposed aggregate		**10**	2	3
Fair-face cladding		7	6	2
GRC (glass reinforced cement)	2	7	6	
Insulated sandwich panels	2	8	4	1
Painted finish	4	9	2	
Reconstructed stone		5	**8**	2
Stone faced panels (ashlar)	1	3	**9**	2
Stone faced panels (random)	2	7	5	1
Terracotta faced	2	8	5	
Other (please state)			1: slate faced	1: granite faced 1: hand set on site
Total (by category)	**13**	**71**	**69**	**13**

TABLE 4 Uses for PCC products (votes cast by the 15 respondents)

	COMMERCIAL/ OFFICE	INDUSTRIAL	RESIDENTIAL	RETAIL	OTHER
Brick faced	**8**		2	2	
Cast stone	**8**		4	3	
Exposed aggregate	7	1	1	1	1
Fair-face cladding	5	1	3	3	1
GRC (glass reinforced cement)	4			1	2: hotels
Insulated sandwich panels	5	1	1	1	
Painted finish	1	1			1
Reconstructed stone	**10**		4	4	2: airports
Stone faced panels (ashlar)	7		1	2	1
Stone faced panels (random)	3				1
Terracotta faced	4		1		
Other (please state)	1: granite faced				
Total (by category)	**63**	**4**	**17**	**17**	**9**

building project. Other uses for PCC were mainly residential, retail and some leisure projects, with a very small number of people citing industrial projects. Despite the striking distribution of votes in response to this question, there was no consensus on the building type(s) for which PCC was most suitable.

FACTORS AFFECTING THE USE OF PCC

The interviewees were asked to identify the most important opportunities and barriers or impelling and impeding factors (after Gray, 1995); their responses are shown in Tables 5 and 6. A list of possible factors was drawn up from literature (Glass and Baiche, 2001; Dawson, 2003) and used as an *aide memoire*. Participants selected up to 10 opportunities and 10 barriers, and assigned an importance rating to their choices, where L = lower importance (i.e. 'this issue comes up from time to time'); M = medium importance (i.e. 'this is considered regularly'); and H = higher importance (i.e. 'this is considered on every job').

To provide an indication of the relative standing of the factors, the number of responses (N) was multiplied by the relative importance (I) assigned to each response i.e. low importance scores 1; medium importance scores 2; and higher importance scores 3 points, to give a total score of (N) x (I) for each factor (after Soetanto *et al*, 2004). The maximum NI value possible is 45 (i.e. all 15 respondents giving the factor a 'highest importance' rating); for ease of reading, the NI values have been converted to percentages of this maximum.

OPPORTUNITIES/IMPELLING FACTORS

This section reviews the most significant opportunities for PCC, in this case the top seven in terms of relative importance scores. These were cited by seven or more of the interviewees and scored most highly in terms of their importance (more than 30% of the maximum NI value).

Buildability (score = 75.5%)

12 interviewees noted that PCC's high degree of buildability maximized the contractors' chances of being able to deliver the building; elimination of trades on site was also thought to be a key benefit. Compared with traditional brickwork, the use of PCC reduced labour requirements on site, needed less scaffolding, involved fewer activities and thus interfaces to be dealt with by site managers. Indeed, Arditi *et al* (2000) suggest that compatibility problems should not be an issue with precast systems provided that designers and manufacturers consult one another regularly.

Quality (score = 71.1%)

Comments on the consistency of PCC were made by 12 respondents, for example, observing that the factory-based manufacturing environment made it easy to

TABLE 5 Opportunities/impelling factors that encourage the use of PCC

FACTOR	NO. OF RESPONSES (N)	RELATIVE IMPORTANCE SCORES AND TOTAL (MAX. NI VALUE = 45)	OVERALL RATING (% OF MAX. NI VALUE)
Buildability	12	10 H; 2 M (34)	75.5
Quality	12	8 H; 4 M (32)	71.1
Speed of erection	11	7 H; 4 M (29)	64.4
Off-site production/prefabrication	10	6 H; 4 M (26)	57.7
Cost competitiveness	10	5 H; 5 M (25)	55.5
Aesthetic/architectural image	8	4 H; 3 M; 1 L (19)	42.2
Previous personal experience	7	4 H; 2 M; 1 L (17)	37.7
Level of confidence in the product	5	3 H; 2 M (11)	24.4
Flexibility in design and shape	5	1 H; 4 M (11)	24.4
Durability	4	2 H; 1 M; 1 L (9)	20.0
Panel size/dimensions	4	1 H; 3 M (9)	20.0
Alternative to natural stone	4	1 H; 2 M; 1 L (8)	17.7
Environmental/sustainability	4	4 M (8)	17.7
Design information; quality, timing and know-how	3	2 H; 1 M (8)	17.7
Logistics and craneage	3	1 H; 2 M (7)	15.5
Previous project teams' experience	3	1 H; 2 M (7)	15.5
Weathering	3	1 H; 2 M (7)	15.5
Thermal mass	3	3 M (6)	13.3
Client requirement/preference	3	2 M; 1 L (5)	11.1

A further 14 issues were cited by one or two interviewees only: Track record/history of its use; Joints and interfaces; Lead time; Thermal insulation; Local authority requirement/preference; Tolerances; Cheaper than natural stone; Speed of production in the factory; Soundproofing; Net lettable area/space utilisation; Fixings; Accuracy; Range of new finishes; Fire protection.

control the quality of finish. When citing the term 'quality', the interviewees referred to physical aspects of PCC (e.g. colour, dimensional accuracy) in addition to other issues such as logistics and customer service. People commented that they had been 'surprised by the quality and degree of skill in the production process' and were pleased with the precision, consistency, delivery process and aesthetic appearance. Their responses covered a number of aspects of quality, supporting the notion of a heuristic decision-making process (Ballal and Sher, 2003).

Speed of erection (score = 64.4%)

This was raised by 11 interviewees. PCC was thought to provide a rapid, watertight enclosure for fixing and finishing trades, affirming work by Gibb and Brand (1996). There was also the benefit of reduced preliminaries, including the cost of crane hire. One interviewee said: '[PCC] comes to site ready to erect and goes up very quickly; it's fantastic to see the speed at which you can get the building watertight.' This is congruent with Dawson (2003) who notes that panels delivered in a pre-arranged sequence facilitate just-in-time erection and omit double-handling on site.

Off-site production/prefabrication (score = 57.7%)

Of the 10 people who cited off-site benefits, one interviewee stated: 'The worst place to build a building is on a building site, the best place to build a building is in a factory because it is a more controlled environment. It doesn't rain or get cold in a factory, the [workers] are there, that's where they have to work everyday, so they become experts in working in their factory and [with the] building components.' The score for this factor confirms the current interest in off-site manufacturing techniques (after Gibb, 1999).

TABLE 6 Barriers/impeding factors that discourage the use of PCC

FACTOR	NO. OF RESPONSES (N)	RELATIVE IMPORTANCE SCORES AND TOTAL (MAX. NI VALUE = 45)	OVERALL RATING (% OF MAX. NI VALUE)
Lead time	9	6 H; 3 M (24)	53.3
Initial cost	8	5 H; 3 M (21)	46.6
Logistics and craneage	8	1 H; 7 M (17)	37.7
Aesthetic/architectural image	6	5 H; 1 M (17)	37.7
Joints and interfaces	6	4 H; 2 M (16)	35.5
Weathering	6	4 H; 2 M (16)	35.5
Fixings	6	3 H; 3 M (15)	33.3
Flexibility in design and shape	6	3 H; 2 M; 1 L (12)	26.6
Repair and vulnerability	4	4 H (12)	26.6
Tolerances	5	1 H; 4 M (11)	24.4
Panel size	4	2 H; 2 M (10)	22.2
Local authority requirement/preference	4	1 H; 3 M (9)	20
Speed of erection on site	4	4 M (8)	17.7
Level of confidence in the product	3	1 H; 2 M (7)	15.5
Quality of finish	3	1 H; 2 M (7)	15.5
Speed of production in the factory	3	3 M (6)	13.3
Risk – link to health and safety	3	1 H; 2 L (5)	11.1

A further 21 issues were cited by one or two interviewees only: Alternative to natural stone; Environmental/sustainability; Net lettable area/space utilisation; Flexibility of design and shape; Design information – quality, timing and know-how; Durability; Difficult to satisfy architects; Track record/history of its use; Design capability of the PCC industry; Capability of the main structure to support (expense); Stigma and perception; Not fashionable; Small specialist market; Loading on building structure – effect of deflections; Previous project teams' experience; Thermal insulation; Mass production – poor quality; Standardisation – number of moulds; Airtightness; Deflections and movement; Consistency.

Cost competitiveness (score = 55.5%)

When citing 'cost competitiveness', interviewees referred to long-term savings on construction programme, labour, crane hire, etc., but also recognized that a high-quality product would result in fewer remedials to be carried out after practical completion. Although 10 of the 15 interviewees recognized the overall 'value' of PCC, it is important to note that initial cost appears as the second most important of the barriers, although with a lower overall score.

Aesthetic/architectural image (score = 42.2%)

This was mentioned by eight respondents specifically and by others indirectly, confirming its importance as cited by Glass (2000b) and Freedman (2001). One noted that, when compared with glass façades, 'PCC is good at giving a complementary aesthetic; a more rugged, massive, solid appearance'. Blake and Southcott (2002) explain that 'a high standard of finish' coupled with speed and buildability were critical factors in deciding to use PCC on a 100,000 m^2 residential project in Vauxhall, London. This factor also appears on the list of barriers, but with a lower overall score.

Previous personal experience (score = 37.7%)

This factor was rated highly despite being mentioned by fewer than half of the interviewees, confirming that personal experience and heuristics are influential on the decision to specify PCC (e.g. Ballal and Sher, 2003). It was clear that if people had confidence in PCC they were more likely to become repeat customers. Indeed, the factor 'level of confidence in the product' was next highest rated, albeit at a much lower level of 24.4%. This supports recommendations in Goodchild and Glass (2004) who emphasize the need to 'build confidence' in the precast option.

BARRIERS/IMPEDING FACTORS

This section reviews the most significant opportunities for PCC, in this case the top seven in terms of relative importance scores. These were cited by six or more of the interviewees and scored most highly in terms of their importance (more than 30% of the maximum NI value).

Lead time (score = 53.3%)

Of the nine interviewees who cited 'lead time', most discussed the need to pre-book production slots in the factory – if this was not done sufficiently early in the process, then PCC could be branded 'inflexible'. One noted that 'anything you've got to wait for [on site] is a problem' and went on to explain that in contrast to PCC, traditional construction gave them control of the programme. Walker (2004) cites existing factory workload and scale of the project as possible reasons for the lead time required. He suggests that 'precasters need to allow six to eight weeks for mould building and reinforcement fabrication' and recommends the early involvement of the precaster, which was also stated clearly in Arditi *et al* (2000) and Glass and Baiche (2001).

Initial cost (score = 46.6%)

Cost issues appear under both drivers and barriers. Eight of the respondents believed 'initial costs' for PCC could appear more expensive than traditional construction and felt that they did not always understand the link between efficient mould use, panel repetition and the quoted costs. For cladding panels, it is critical to attain repeat mould use to prevent initial costs escalating. Dawson (2003) explains that 30 identical casts from a timber mould give an optimum unit cost, but as repetition reduces to 10 castings or less, the cost rises rapidly, by up to seven times. While acknowledging that factory production does cost more than on-site construction, Walker (2004) counters that use of PCC can result in programme savings, for example, by reducing preliminaries.

Logistics and cranage (score = 37.7%)

Eight interviewees noted that making PCC cost effective often resulted in large panels, which in turn required high-capacity (tower) cranes for lifting. With only one or two such panels arriving per load, the overall impression was that PCC could be difficult to handle, especially on congested sites. However, this view somewhat contradicts the 'speed of erection' factor cited as an opportunity. In his paper responding to such comments, Walker (2004) notes that effective panelization could lead to faster rates of construction than traditional methods such as brickwork. Designers, manufacturers and main contractors called for better guidance on this issue.

Aesthetic/architectural image (score = 37.7%)

Six of the respondents thought that some designers did not like the aesthetic of PCC, seeing it as unfashionable and 'only for car parks'. Interviewees suggested that PCC was still associated with the 'grey, streaky' residential high-rise towers of the 1960s. Arditi *et al* (2000) agree that to some extent architectural creativity may suffer from the use of precast concrete systems, but case studies in Dawson (2003) illustrate the visual quality of PCC finishes.

Joints and interfaces (score = 35.5%); weathering (score = 35.5%); fixings (score = 33.3%)

Six people cited practical concerns regarding 'joints and interfaces', focusing on the need for high levels of workmanship to ensure sufficient weatherproofing, particularly around windows. Interviewees discussed early identification and coordination of interfaces and the need for the precaster to make lifting and fixing provisions absolutely clear, which aligns with findings in Ledbetter (2003) relating to complexity in the cladding supply chain. Several interviewees cited weathering throughout their commentaries, which has been covered in detail by Hawes (in Taylor, 1992), Dawson (2003) and others, but there appears to be a need for further guidance.

RESPONSE SUMMARY

Although this research has focused on a small sample of experts, it is valid to explore briefly the disparity between responses in the previous two sections. A simple illustration of the level of difference in responses to the opportunities and barriers for PCC, respectively, is shown in Figure 1. Although for both categories the top seven and five factors, respectively, obtained the lion's share of the scores, it is clear that there is considerable

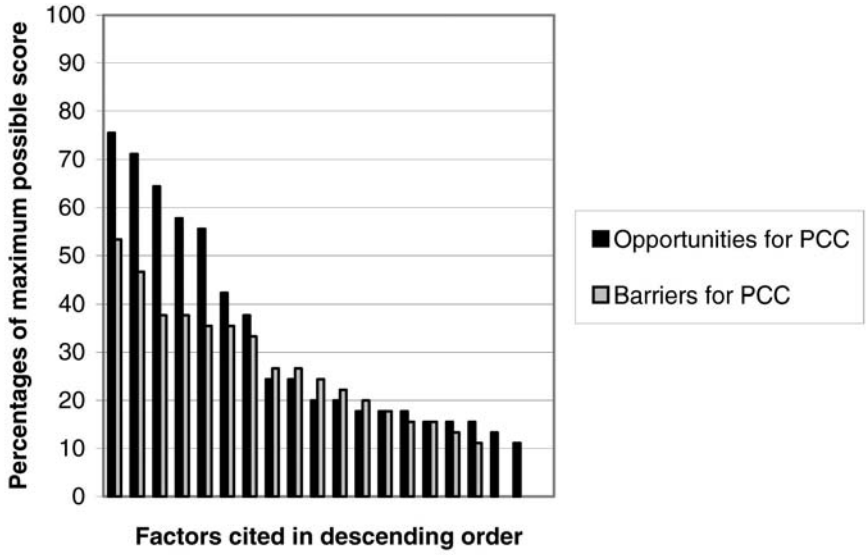

FIGURE 1 Comparison of relative importance scores for opportunities and barriers, shown as percentages against the theoretical maximum score of 45 (i.e. 15 respondents all awarding the highest score of 3 to any one factor)

disparity between the level of consensus. There appears to be strong consensus on the most significant opportunities, whereas the scores for barriers follow a shallower curve, indicating that a slightly broader set of factors are taken into consideration as being important in decision-making. This is an interesting point that could be explored through further research.

FUTURE RESEARCH AND DEVELOPMENT ACTIVITIES

In the final part of the interview, the researcher used a series of open-ended questions to explore broader views on PCC as a product now and in the future covering satisfaction levels, service delivery, areas for improvement, customer needs and market potential. This attracted a broad range of responses from the interviewees, allowing people to expand on previous answers and encouraging them to make suggestions about what precast concrete suppliers should be doing to improve their share of the cladding market.

Levels of satisfaction with PCC

The participants in general described themselves as 'very satisfied' with only one person saying they had not been particularly satisfied ('the image was poor... the ones from the 1960s and 70s are bad... and people don't check to see how products have moved on'). It was thought to be particularly important to select the right company in terms of capacity, quality and attitude; when this worked well, the manufacturer would integrate well with the design team. This aligns with recommendations in Glass (2000b) and Freedman (2001) relating to the importance of selecting the 'right' precaster for the job and the need for their close collaboration with the team.

Possible improvements that could be made by manufacturers

The interviewees had a number of suggestions such as early identification and coordination of interfaces and for the precaster to make lifting and fixing provisions clear. One person described how handling sockets for use in the factory had not been particularly well concealed and another mentioned the complexity of fixing details at corners. Early, transparent information was requested from the precasters on fixings and other possible on-costs such as scaffolding, etc. Another interviewee described how important it was for the

precaster to subcontract out work responsibly (such as fixings) because poor work in that area could compromise the whole project. A number of people cited the benefits of a proactive approach, as in Glass and Baiche (2001); an example was given of a European precaster who, having visited the designers, had gained their confidence through his 'knowledge, experience and bright ideas'. It was felt that manufacturers should be more considerate to architectural requirements, aesthetics and appearance. Walker (2004) observes that manufacturers are sensitive to this and suggests that the early involvement of the precaster's design resources is critical.

Directions for future research and development

The interviewees provided a broad range of ideas for future R&D, which are summarized in Table 7 and cross-referenced with the literature where appropriate. The suggestions include improvements to production techniques to better meet customers' needs, provision of quality guarantees, developmental work on finishes and improved working relationships within the supply chain.

Possible reasons for people not choosing PCC

Given that PCC holds only about 5% of the UK cladding market, participants were asked to suggest why this was the case and why people were not choosing to

TABLE 7 Some of the major areas for improvement according to interviewees

PROBLEM OR QUESTION	POSSIBLE AREA FOR IMPROVEMENT/SOLUTION
Ensure quality	For example, the precaster could supply 'guarantees of performance', so people could be sure how panels would weather.
Panels too heavy	Make panels lighter in some way, perhaps being hollow, or incorporating other materials. GRC, a lighter option for cladding panels, is described in Dawson (2003) and Walker (2004).
Are the right tolerances actually being specified? Is there an alternative to sealants?	Measure existing projects and compare the achieved tolerance with that which was specified. Investigate gasket arrangements as a possible alternative method.
Reliance on old-fashioned timber moulds	Investigate flexible, long-lasting moulds to shorten lead-time. The use of self-compacting concrete is having a significant impact on production methods and is likely to have an influence here (The Concrete Society/BRE, 2005).
Make finishes 'more fashionable'	Use polymer-based facing materials, integrate recycled/waste materials, etc.; aim for more variation, flexibility and freedom in design.
High embodied energy in Portland cement	Precasters could give customers the option to use less cement, explaining how that would affect the product (i.e. curing times, strength). Ways in which the sustainability performance of concrete can be improved are discussed further in Pocklington and Glass (2002).
Complicated interfaces with other disciplines	Develop a toolkit for managing interfaces, 'a way that various subcontractors can learn to work together effectively'. Similar to the specification tool described by Ledbetter (2003)
What is the state of the UK industry's design capabilities compared with the European market?	Gauge the current situation and establish what lessons could be learnt from mainland European precasters, perhaps building on work by Naert *et al*, (2002).
Preconceptions or a 'social stigma' about precast concrete amongst some professions	Undertake work on perceptions, myths and stigmas, as explored in Glass (2000a). Local authority planners, it appears, are most likely to retain such views.
Incompatibility with industry drafting software	Develop an integrated software package to link StruCAD, AutoCAD and frame design.
Lack of predictability of weathering	A photographic survey of buildings would be a useful addition to Dawson (2003) providing guidance on weathering and photos of how precast buildings look after five, 10 and 20 years.
Few standard details available; need to commission specialists to evaluate panel design.	Some 'standardization in terms of details, fixings, composition and insulation' would be desirable, but without limiting design (Arditi *et al*, 2000).

specify PCC (the question therefore required some degree of supposition on their part). Five major themes arose in response to this question.

First, the stigma still exists that choosing PCC means choosing 'drab, grey concrete walls', confirming concerns expressed in Arditi *et al* (2000); four interviewees suggested that this preconception was a major problem for precast concrete with town planners in particular preferring natural stone finishes. Second, PCC was associated with 'dull', 'boxy' architecture and as such was not seen as fashionable by architects who preferred glassy, curvy, lightweight buildings. However, two of the three people who cited this as a problem also mentioned that energy-efficiency improvements were driving them to use heavier weight materials such as precast flooring in their designs to improve thermal mass (Glass and Baiche, 2001).

The third theme was a lack of marketing: four interviewees stated that architects were not 'seeing the consistency and quality of PCC' because the industry was not marketing itself sufficiently, which has resulted in a lack of awareness/familiarity with the possibilities. Several interviewees discussed practical constraints such as initial costs, lead time and panel weight as everyday difficulties that may hamper the use of PCC. They also mentioned weathering and fear of corrosion of reinforcement, the mechanisms of which are explained in Dawson (2003). Finally, two interviewees noted there were plenty of options open to them to clad a building, many of which were equally attractive, but cheaper and more flexible than PCC – rainscreen cladding was cited as a technology that had effectively 'killed off' precast cladding.

Market potential for PCC

All the respondents had ideas on how the industry could increase its share, most of which fell into the category of market development activities. Several people discussed the need for a major programme of promotion, much the same as that described by Naert *et al* (2002), in which the industry should:

- emphasize benefits: for example, that PCC is complementary to glass and metal façade systems, does not rely on skilled bricklayers or stone masons on site and brings all the benefits of off-site manufacture
- overturn preconceptions: emphasize that 'you get what you pay for' – respondents cited the need to help people comprehend costs associated with their expectations and noted that there was 'no point providing good technical information if people still think it [PCC] is a horrible material'
- capture information: on projects, best practice and sustainability issues (e.g. recycling, waste, energy efficiency). One respondent described how the best examples were to be found where the precaster considered itself 'part of the complete building envelope team'. Another said that the best examples were about 'relationships, trust and taking ownership'
- raise awareness: interviewees called for precasters to 'go out there and convince people', visit practices directly, target trade magazines and institutions stating that 'communication is the key and it [the PCC industry] is not communicating what it is doing'.

CONCLUSIONS

A study of the perceptions of precast concrete cladding was undertaken with the aim of assessing awareness and use of PCC in the UK, identifying generic factors affecting its take-up and possible R&D directions. Interviews were undertaken with 15 experienced, senior individuals from a range of professional/trade groups who were familiar with the use of stone-faced, reconstituted stone, cast stone and brick-faced precast cladding on predominantly commercial buildings. The research has provided an overview of current perceptions of the product and manufacturers' level of service delivery.

The interviewees identified major opportunities/impelling forces thought to encourage the use of PCC and major barriers/impeding forces thought to discourage the use of PCC. A scoring system was applied to combine the number of responses for each factor with the relative importance assigned to each response, giving percentage values against a maximum possible score, as follows.

OPPORTUNITIES/IMPELLING FACTORS

- Buildability (75.5%)
- quality (71.1%)
- speed of erection (64.4%)

- off-site production/prefabrication (57.7%)
- cost competitiveness (55.5%)
- aesthetic/architectural image (42.2%)
- previous personal experience (37.7%).

BARRIERS/IMPEDING FACTORS

- Lead time (53.3%)
- initial cost (46.6%)
- logistics and craneage (37.7%)
- aesthetic/architectural image (37.7%)
- joints and interfaces (35.5%); weathering (35.5%)
- fixings (33.3%).

'Aesthetics/architectural image' appeared on both lists, indicating that this issue is a matter of personal preference and/or previous experience with PCC. Cost also appeared twice; long-term value was thought of as a positive attribute, whereas initial costs were thought of as negatively expensive. This suggests that improvements are necessary in the quality and availability of cost data and/or the development of better decision support frameworks relating to short- and long-term costs, a view supported by some interviewees. The fact that issues such as buildability and speed of erection were cited as important positive factors confirms PCC's benefits as a product made off-site, but negative views expressed on lead time and logistics/cranage suggest that these benefits are neither well understood nor exploited.

Interviewees suggested that market development activities on the part of the precast concrete cladding industry were needed to raise awareness of the possibilities and overturn entrenched preconceptions. Information on technical aspects (such as definitions, costs, tolerances, fixings and finishes) and landmark examples were requested by the interviewees to raise confidence in the product. The major increase in market share for PCC in Belgium, reported by Naert *et al* (2002), demonstrates the impact of a well-directed marketing programme; the results of this research provide sufficient early findings for the UK precast concrete industry to initiate a similar campaign.

Further to this, a number of directions for research and development were proposed including improvements to mould technology, mix design, finishes, communication within the supply chain, software integration and predictions of long-term weathering performance. The respondents generally held positive views of their experience in using PCC, but cited a range of aspects that required further research to improve the product and level of service delivery from precast manufacturers. By addressing such problems within production and construction, interviewees felt that PCC may be able to overcome criticisms of its cost, appearance and flexibility, thereby improving the likelihood of it being considered a cost-effective and fashionable façade solution and hence increasing its share of the UK cladding market.

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