

Most popular methods for minimizing in-situ concrete waste in the UK

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Abstract: In recent decades, construction waste has become a significant environmental problem in many large cities around the globe. It has been revealed that the material waste in a great number of construction sites is over the acceptable limits. Concrete has been proven to be a leading construction material for more than a century and hence concrete waste has been recognized as a major problem in the construction industry, particularly in-situ concrete waste. This paper aims to explore the common methods of on-site concrete waste minimization in the UK, and to identify the most preferred practices, and to rank all of the current methods used by construction companies in the UK, in terms of their benefits for eliminating or minimizing concrete waste on-site. In order to obtain the required data, a questionnaire survey was conducted. The participants were selected from different professional roles including, consultants, general contractors, project managers and site superintendents. The results have illustrated that “Use of pre-fabricated building components”, “Education and training” and “Purchase management” as the most recommended methods in the UK for minimizing on-site concrete waste among the current practices.

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1. Introduction

In recent decades, construction waste has become a significant environmental problem in many large cities around the globe (Begum et al., 2006). Construction and demolition (C&D) waste is considered as one of the major contributors to the total waste stream due to its sheer volume. It has been revealed that the material waste in a great number of construction sites is over the acceptable limits (Kulathunga et al. 2006). For instance, in Australia the National Waste Minimization and Recycling Strategy has estimated that each year 14 million tonnes of solid waste is deposited in landfill (ibid.). Teo et al (2001) reported that construction waste is estimated to account for approximately 30 per cent of solid waste in Canada. In the USA, it produces approximately 20 per cent of overall landfill waste volume, while in the UK, it produces more than 50 per cent. In Hong Kong, in 2001, the construction and demolition sector produced more than 40 per cent of the total waste (Wong et al., 2004). Concrete has proven to be a leading construction material for more than a century. It is estimated that the annual, global production of concrete is 1 m³ (approximately 2.5 tonnes) per capita (Neville, 2003). Concrete has been recognized as one of the main waste materials in construction projects (Kofoworola and Gheewala, 2009).

This paper aims to explore the common methods of on-site concrete waste minimization in the UK, and to identify the most preferred practices, and to rank all of the current methods, which are used by construction companies in the UK.

2. Recent Studies

Recent studies illustrate different methods for minimizing the concrete waste in construction sites such as the “Reuse and recycling operation”, “Improvements of on-site waste management practices” (Osmani, 2012), “Environmental management system”, “On-site C&D waste sorting” (Weisheng and Hongping, 2010), “Use of prefabricated building components” (De Silva and Vithana, 2008; WRAP, 2007; Poon et al., 2004a), “on-site reuse of materials”, “On-site waste conservation”, and “Use of information technology on-site” (Tam, 2008). Moreover, education and training, green building and design, green procurement, green roof technologies, lean construction, prefabrication and waste management are also considered as major methods for the promotion of sustainable construction (Bakhtiar et al, 2008). Table 1 summarizes some recent methods for concrete waste minimization in construction projects.

3. Methodology

First, a literature review was conducted to obtain insights into the on-site concrete waste minimisation in construction. Second, a questionnaire was disseminated to the UK’s top construction contractors and consultants (e.g. see Osmani et al. 2007). A quantitative approach was used to collect the information. In order to obtain the data a questionnaire survey was conducted. It has been started with a comprehensive review of existing studies, which discovered several methods for minimizing the on-site concrete waste in construction projects. This led to the

development of a questionnaire that included eight multiple choices questions. The result of the

questionnaire has been presented in the section 3.

Table 1. Concrete waste minimization methods

Methods	Literature
Use of pre-fabricated building components	(Bakhtiar et al, 2008; De Silva and Vithana, 2008; Poon, 2007; WRAP, 2007; Poon et al.,2004a)
Waste prevention in onsite transport (Include use of volumetric trucks to handle the exact needs of the quantities)	(Esin and Cosgun, 2007; Poon, 2007)
Onsite waste conservation	(Saghafi and Teshnizi, 2011; Tam, 2008)
On site reuse	(Osmani, 2012; Tam, 2008; Esin and Cosgun, 2007; Poon, 2007)
Central area for cutting and storage	(Weisheng and Hongping, 2010)
Onsite waste recycling operation	(Osmani, 2012; Saghafi and Teshnizi, 2011; Esin and Cosgun, 2007; Poon, 2007)
Identification of available recycling facilities	(Osmani, 2012; Kofoworola and Gheewala, 2009; Esin and Cosgun, 2007; Poon, 2007)
Use of Information Technology onsite (e.g. BIM in order to avoid mistakes & misfit designs)	(Tam, 2008)
Implementation of environmental management systems	(Bakhtiar et al, 2008; Poon, 2007)
Education and training	(Bakhtiar et al, 2008)
Governmental incentives for practices in reducing wastes	(Osmani, 2012; Weisheng and Hongping, 2010)

The purpose of these questionnaires is to identify the on-site concrete waste minimization methods and their rankings in construction projects, as well as measuring the importance of each method in terms of quantity and price and their effect on the projects.

The questionnaire contained two sections:

- Section 1- Interviewees background information (four questions);
- Section 2- existing methods of on-site concrete waste minimization and any recommendations (four questions).

The questions contained in section 2 were of an open-ended type, and were directly related to the achievements of the literature reviews.

A stratified random method was adopted for sampling, which provided a more representative sample. In order to select the participants from each stratum, a simple random sampling technique was adopted through the use of random number tables (Saunders et al, 2009; White, 2000). Stratified sampling is appropriate where the population occurs in 'distinct' groups or strata (Fellows and Liu, 2009). The reason for implementing a probability sampling was that it was necessary to carry out a statistical analysis (White, 2000) in order to analyze the collected data. Furthermore it was necessary to use the representative sample in order to generalize the outcomes (Saunders et al, 2009). The study used Statistical Package for Social Science (SPSS) to analyze the data.

The participants for the questionnaire were selected from different positions includes, consultants, general contractors' project managers, and site superintendents. The specific population criteria (Eisenhardt and Graebner, 2007) were determined as:

(1) holding a managerial or directory position, and (2) having been involved in multi-storey concrete-structure building development projects.

Participants were chosen from the UK's 100 top construction contractor companies, and the top 100 consultant companies.

A list was created by using the following directories:

- 100 leading construction contractors companies in the UK
- 100 top consulting companies in the UK.
- Lists of on-going concrete-structure developments in the UK.

In accordance with Fellows and Liu (2008), and in order to improve the questionnaire by filling in gaps and determining the time required for, and ease of, completing the exercise, five pilot questionnaires were conducted with people of similar characteristics to those of the survey population. This number of participants could sufficiently include major variations among the survey population (Saunders et al, 2009).

According to the sampling method, a total number of 196 questionnaires have been sent.

In order to follow the survey's ethical rules, and to collect as relevant as possible in the questionnaire, participant information sheets and consent forms were sent to the participants. (Fowler, 2002) with the questionnaires via mail, accompanied by a pre-paid self-addressed envelope.

The process of getting the questionnaires out and back (by mail) took six weeks. The participants were asked to complete and send back the questionnaires within 10 days of receiving them. Within three days of the deadline passing the telephone follow-ups were

managed, for those candidates who had not returned a completed questionnaire, indicating that the deadline was extended to 10 days after the reminder mail-out. Within three days of the second deadline, a further reminder was sent out with another new 10-days deadline. The questionnaire survey administration concluded at the end of the sixth week of the survey with 101 completed responses.

According to Saunders et al (2009) in order to have a reliable survey, a total number of at least 60 responses were needed.

The response rate was based on the total number of questionnaires sent for the survey and the total number of respondents. The total of 196 questionnaires has been sent, and 101 participants responded to the survey. Therefore the active response rate for the survey was 51.5%.

Mean rating is calculated as Eq. (1), where:

W = Weight of answer choice

X = Response count for answer choice

$$(1) \quad \frac{X1W1 + X2W2 + X3W3 + \dots + XnWn}{\text{Total}}$$

4. Analysis and Results

Table 2 below illustrates the active response rate. The response rate is based on the total number of questionnaires for the survey and the total number of respondents. A total of 196 questionnaires were sent, and 101 specialists responded to the survey. Therefore, the active response rate for the survey was 51.5 per cent.

Project consultants with more than 54.2 % had the highest active response rate, whereas Site superintendents with above 40.8 % had the lowest response rate in this survey. Table X represents the number of sent questionnaires and number of completed received questionnaires, plus the percentage of participation of each group.

Role	Sent	Received	Participation %
Contractor’s project Manager	49	20	40.8
Site superintendent	53	22	41.5
Project consultant	48	26	54.2
Engineer	46	23	50.0
Unspecified	0	10	
Total	196	101	51.5

Within the questionnaires, the participants were asked to express their understanding and experience of the approaches to minimising concrete waste on-site (in-situ). Participants were asked to rate the on-site concrete waste minimising methods in terms of:

- a) Cost of implementation (Table 4)
- b) Difficulty of implementation (Table 5)
- c) Cost efficiency (Table 6)

d) Overall value of spending on them to make savings or minimise waste (Table 7)

The results in Table 4 show the ranking of methods in terms of cost of implementation. Participants were asked to rate 1 as very expensive, and 5 as very cheap.

Table 4. Current on-site (in-situ) concrete waste minimization methods in the UK in terms of cost of implementation.

On-site concrete waste minimising methods	Responses					Mean rating	Ranking
	Percentage						
	1	2	3	4	5		
Governmental incentives for practices reducing wastes	0	0	12	38	50	4.38	1
Purchase management	0	9	17	37	37	4.02	2
On-site inventory management	3	9	25	31	32	3.8	3
Waste prevention in on-site transport	2	10	25	35	28	3.77	4
Identification of available recycling facilities	6	6	26	41	21	3.65	5
Education and training	6	10	28	36	20	3.54	6
On-site waste conservation	7	13	40	24	16	3.29	7
Use of Information Technology on-site	7	15	45	19	14	3.18	8
Implementation of environmental management systems	8	12	47	23	10	3.15	9
On-site reuse	8	13	46	23	10	3.14	10
Central area for cutting and storage	9	12	49	23	7	3.07	11
Quality Management	10	22	48	14	6	2.84	12
On-site waste recycling operation	11	23	47	14	5	2.79	13
Use of pre-fabricated building components	10	21	51	16	2	2.79	14
Proper site layout planning	12	29	46	13	0	2.6	15

1 for very expensive, and 5 for very cheap

Therefore, the top three preferred methods in the UK in terms of cost of implementation were: governmental incentives for practices reducing wastes, purchase management, and on-site inventory management.

Question 5 of the questionnaire asked about the ranking of methods in terms of difficulty of implementation. Participants were asked to rate 1 for very hard to be implemented, and 5 for very easy, and Table 5 illustrates the result.

Table 5. Current on-site (in-situ) concrete waste minimization methods in the UK in terms of difficulty of implementation.

On-site concrete waste minimising methods	Responses					Mean rating	Ranking
	Percentage						
	1	2	3	4	5		
Education and training	0	0	13	38	49	4.36	1
Purchase management	0	9	18	37	36	4	2
Onsite inventory management	3	9	26	31	31	3.78	3
Identification of available recycling facilities	2	10	25	35	28	3.77	4
Use of pre-fabricated building components	6	6	26	41	21	3.65	5
Quality Management	6	10	28	36	20	3.54	6
Governmental incentives for practices in reducing wastes	5	13	40	24	18	3.37	7
Use of Information Technology onsite	6	16	34	26	18	3.34	8
Implementation of environmental management systems	7	12	40	26	15	3.3	9
On site reuse	7	10	44	29	10	3.25	10
Proper site layout planning	8	9	45	28	10	3.23	11
Onsite waste conservation	9	22	48	15	6	2.87	12
Waste prevention in onsite transport	10	23	47	15	5	2.82	13
Onsite waste recycling operation	9	23	51	15	2	2.78	14
Central area for cutting and storage	11	29	46	14	0	2.63	15

1 for very hard to be implemented, and 5 for very easy.

As can be seen, the three easiest methods in terms of implementation are: education and training, purchase management, and on-site inventory management.

The results in Table 6 show the ranking of

methods in terms of cost efficiency. Participants were requested to rate 1 for not efficient at all, and 5 for very efficient.

Table 6. Current on-site (in-situ) concrete waste minimization methods in the UK in terms of cost efficiency.

On-site concrete waste minimising methods	Responses					Mean rating	Ranking
	Percentage						
	1	2	3	4	5		
On-site reuse	0	2	21	37	40	4.15	1
Governmental incentives for practices reducing wastes	0	8	19	36	37	4.02	2
Purchase management	5	9	23	31	32	3.76	3
Education and training	2	10	25	35	28	3.77	4
Identification of available recycling facilities	6	6	26	41	21	3.65	5
Implementation of environmental management systems	7	16	34	25	18	3.31	6
Waste prevention in on-site transport	5	13	40	24	18	3.37	7
On-site inventory management	6	16	34	26	18	3.34	8
Use of pre-fabricated building components	7	10	44	29	10	3.25	9
Use of Information Technology on-site	8	9	45	28	10	3.23	10
On-site waste conservation	8	12	47	23	10	3.15	11
Quality Management	8	13	46	23	10	3.14	12
Central area for cutting and storage	15	25	40	15	5	2.7	13
On-site waste recycling operation	22.5	20	32.5	22	3	2.63	14
Proper site layout planning	13	30	40	17	0	2.61	15

1. for not efficient at all, and 5 for very efficient.

As can be seen, the three highest ranked methods in terms of cost efficiency are: on-site reuse, governmental incentives for practices reducing waste, and purchase management.

The results in Table 7 show the ranking of methods in terms of the overall value of spending on them to make savings or minimize waste. Participants were asked to rank 1 for improper and 5 for excellent.

Table 7. Current on-site (in-situ) concrete waste minimization methods in the UK In overall.

On-site concrete waste minimising methods	Responses					Mean rating	Ranking
	Percentage						
	1	2	3	4	5		
Use of pre-fabricated building components	0	2	21	37	40	4.15	1
Education and training	0	8	19	36	37	4.02	2
Purchase management	5	9	23	31	32	3.76	3
On-site inventory management	4	12	21	35	28	3.71	4
Waste prevention in on-site transport	6	6	26	39	23	3.67	5
Identification of available recycling facilities	6	10	28	36	20	3.54	6
Use of Information Technology on-site	7	15	33	24	21	3.37	7
Implementation of environmental management systems	7	16	34	25	18	3.31	8
On-site waste conservation	8	12	40	25	15	3.27	9
On-site reuse	8	10	44	28	10	3.22	10
Governmental incentives for practices reducing wastes	9	9	45	27	10	3.2	11
Quality Management	10	22	45	15	8	2.89	12
Central area for cutting and storage	11	25	44	15	5	2.78	13
On-site waste recycling operation	12	20	43	22.5	2.5	2.835	14
Proper site layout planning	12	30	41	17	0	2.63	15

1 for the improper, and 5 for the excellent

While the participants mentioned a variety of possible and common approaches, most of them referred to "use of pre-fabricated components", "education and training", and "purchase management" as the effective waste reducing methods in the UK.

5. Conclusion

Nowadays, undeniably Legislations and Regulations in the UK are the main drivers for construction waste reduction, for instance rising Landfill Tax, increasing cost for waste disposal, and compliance requirements with Site Waste Management Regulations 2008.

In this paper possible initiatives for minimizing concrete waste in construction sites (in-situ) in the UK were introduced. Following a literature review and researches into the current and previous studies in waste minimization, a list of possible methods has been prepared. The results were concluded through questionnaire survey and by applying quantitative data analyzing methods.

The result was proposed in Table 4, and illustrates "governmental incentives for practices reducing wastes", "purchase management", and "onsite inventory management" are the cheapest methods. "Onsite waste recycling operation", "use of pre-fabricated building components", and "proper site layout planning" are the most expensive methods. Table 5 shows "education and training", "purchase management", and "on-site inventory management" as the easiest methods for

implementation. "Waste prevention in onsite transport", "Onsite waste recycling operation", and "Central area for cutting and storage" are the hardest methods.

As Table 6 illustrates, "on-site reuse", "governmental incentives for practices reducing wastes", and "purchase management" are the most cost efficient methods. "Central area for cutting and storage", "Onsite waste recycling operation", and "Proper site layout planning" are the least cost efficient methods. Finally in Table 7 the results illustrate "use of pre-fabricated building components", "education and training" and "purchase management" as the most recommended methods in the UK amongst the current practices. "Central area for cutting and storage", "on-site waste recycling operation", and "proper site layout planning" are the least recommended methods.

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