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Improving Concrete Delivery Performance between Concrete Plant and Construction Sites - Hong Kong Experience

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Abstract:

A questionnaire survey was conducted in the first quarter of 2003 to investigate the matching of concrete supply between concrete batching plant and construction sites in Hong Kong. Fifty-one respondents provided useful information and it was found that reducing on the time of truckmixer queuing on site is essential for rectifying the inefficiency in matching. The 'miscellaneous waiting time' on site, which is the time between 'the truckmixer arrival on site' time and 'the beginning to unload concrete' time less any time spent actually queuing, was found to be of an average of about 3 minutes. It is suggested to adjust the time of arrival of truckmixer at site by 3 minutes. Hence, it is estimated that queuing time on site will then be shortened by 22%. Besides adjusting the miscellaneous waiting time, the inter-arrival time of consecutive truckmixers should be more accurately estimated by considering the truckmixer volume and the placing method.

Keywords: Concrete, concrete plant, ready mixed concrete, construction, site, simulation, **RMCSIM**

1. Introduction

In Hong Kong, the competition between concrete supply companies is becoming fiercer because of the drop of total value of construction works since 1998. The price of concrete per m^3 fell compared with the previous high demand period (1994 through 1998). To improve the efficiency and competitiveness of concrete suppliers, accurate matching between concrete suppliers and site demands is extremely important. However, the performance of matching between a concrete plant and construction sites was found to be unsatisfactory. The utilization of concrete plant was only about 30% and that of truckmixers ranged from 50 – 80 %, as reported by Anson and Wang (1998). The results from Anson *et al.* (2002) showed that the utilization of concrete plant and that of truckmixers were 37.6% and 61.7 % respectively. This implied that the performance had not improved significantly from 1998 to 2002.

As a concrete plant has only limited resources but needs to supply concrete to many sites with different required times and unloading methods, perfect matching between the plant and the sites is impossible. A survey was conducted by Chan & Kumaraswamy (1997) to evaluate significant factors causing delays in Hong Kong construction projects. As found in that survey, the main reason for delay, which had been analyzed according to different groups of contracting parties (clients, consultants and contractors), is poor site management and supervision. It has also been found by Ying *et al.* (2002) that problems of poor matching usually occur on sites rather than at the concrete plant from the result of simulating concrete delivery operations of one concrete plant supplying ready mixed concrete to multiple sites.

Tang *et al.* (2003) presents a simulation program **RMCSIM,** which is used to simulate a ready mixed concrete plant serving multiple construction sites. In their finding, unsatisfactory concrete delivery performance is most likely due to poor planning and scheduling on site rather than the concrete plant itself. To investigate the unsatisfactory phenomenon occurred on construction sites, a questionnaire survey was conducted in the first quarter of 2003 to investigate what methods could be adopted to achieve improvements in matching between a concrete plant and construction sites. This paper reports the results of this questionnaire survey and provides an analysis of the research finding.

2. The Questionnaire Survey

The authors adopted a rating scale of 1 to 5 in the survey questionnaire where '1' represents 'Strongly Disagree' and '5' represents 'Strongly Agree' to the questions by the respondents. A three-page questionnaire containing more than 30 questions, a covering letter stating the theme of the survey, and the definitions of terms (see below) were given by hand to 51 respondents. They were first asked about their experience and their projects, and were then asked to identify their methods of concrete ordering and give their opinions on the performance of concrete delivery and unloading by truckmixers. Moreover, the respondents were invited to estimate various time durations (e.g. no availability of concrete time, truckmixer queuing time) on site based on their experience. The definitions of terms used in the questionnaire are:

- 'Miscellaneous waiting time' is the time between the truckmixer 'arrive site' time and the 'begin unload' time, less any time spent actually queuing.
- 'No availability of concrete time' is the time difference between 'begin unload' and the specified 'arrive site' time for the first truckmixer. For subsequent truckmixers, it is the time difference between 'begin unload' of the truckmixer under consideration and 'finish unload' of the previous truckmixer.
- 'Washing out plus waiting' time of a truckmixer is the time difference between its 'finish unload' time and its 'leave site' time.
- 'Total truckmixer provision on site' time is the summation of the time of each truckmixer staying on site for the entire pour process.
- 'Pour time' is time between the 'finish unload' of the last truckmixer and the 'begin unload' of the first truckmixer

Basically, the above definitions of terms are sufficient for understanding this paper. Readers can refer to Anson *et al.* (2002) for further details.

3. Survey Findings

Fifty-one construction professionals, including those working on sites and those in the concrete supply companies, responded to the survey (100% response rate because all of them are colleagues or friends of the authors). Table 1 shows information on the respondents' positions, background, experience, and their project details. As more than one placing methods were used in some respondents' sites, the total number of placing methods were greater than the number of respondents. A similar method of analysis was adopted based on the 'Relative Importance Index', as adopted by Kometa *et al*. (1994) to analyze the data collected. Examples of the analysis are shown in the Appendix at the end of this paper. Table 2 shows the comparison of the results of this survey and those from Anson *et al.* (2002). This survey could be regarded as a validation of the previous data collection exercise (2002 survey). The followings are some salient points which need to be discussed.

- Generally, the performance of concrete plant and truckmixer delivery is good. About 75% of the respondents are satisfied with the plants' performance and delivery schedule. Booking of concrete was in general successfully entertained by the plant. Correct grading and quantities of concrete were usually obtained. About 81% of the respondents supported that the delivery of concrete provided by the plant was on schedule, although 'no availability of concrete' occurred on sites and they generally accepted the situation.

- About 73% of the respondents did not appreciate the performance of construction sites. They said that the sites were found not ready quite frequently and as a result truckmixers queuing on site happened quite often (average queuing time is about 11.7 minutes).

Table 1: Information on respondents and their projects

Respondents' Position	Director	Manager	Site Agent	Engineer	Foreman	Inspector	Work Supervisor	Operator	Co-ordinater	Total number
Number	0	2	3	10	4	5	23	3	1	**51**
Academic qualification of respondent	**Diploma/ Certificate**	**Higher diploma/ Higher certificate**	**Bachelor's Degree**	**Master's Degree**	**Doctorate Degree**	**Other (Secondary or below)**	**Total number**			
Number	7	20	12	2	0	10	**51**			
Working experience	**Less than 5 years**	**5 – 9 years**	**10 – 20 years**	**Over 20 years**	**Total number**					
Number	22	21	8	0	**51**					
Contract sum of respondent's project	**Less than 10Million**	**10-50 Million**	**50-100 Million**	**Over 100 Million**	**Total number**					
Number	10	10	14	17	**51**					
Type of respondent's project	**Civil works**	**Building works**	**Drainage works**	**Geo-technical works**	**Maintenance works**	**Total number**				
Number	39	11	0	1	0	**51**				
Average daily concrete needed in respondent's site	**<20m^3**	**20-49.5 m^3**	**50-99.5 m^3**	**100-150 m^3**	**>150 m^3**	**Total number**				
Number	11	19	10	11	0	**51**				
Distance between the concrete plant and site	**4 km approx**	**5 km approx**	**6 km approx**	**7 km approx**	**8 km approx**	**10 km approx**	**12 km approx**	**15 km approx**	**16 km approx**	**Total number**
Number	4	9	1	16	10	3	3	3	2	51
Placing method(s) that respondent's site used	**Crane**	**Barrow**	**Pump**	**Direct tip**	**Backhoe**	**Others**	**Total number**			
Number	32	2	24	15	8	0	**81**			

Table 2: Comparison of the results of two surveys

	Mean value from this survey (in min.)	**Results from Anson *et al.* (2002) (in min.)**
'No availability of concrete on site' time	7.3	6.1
Miscellaneous waiting time	3.9	3.5
Truckmixer queuing time on site	11.7	13.6
'Washing out plus waiting' time	10.3	7.2

Note: 'Mean value' means that the total time (summation of the time related to each truckmixer) is divided by the total number of truckmixers used.

- For the ideal case, 'no concrete on site' or 'time waiting for truckmixer arrival' can be reduced to a minimum when a truckmixer arrives at a site punctually. In other words, once a truckmixer arrives at site, it stops at the placing location without any delay and starts to unload concrete immediately. When it finishes unloading concrete, and after washing, it then leaves the site. However, it is difficult to achieve such an ideal case in practice. The followings are some problems usually arise on site. (1) Truckmixers queue on site because the previous one has not finished unloading concrete, and this increases the 'truckmixer provision on site' time. (2) The placing site or the placing plant is/are not ready, thus the truckmixer is idle on site. (3) Both the truckmixer and the construction site are ready, but no placing work is carried out by the workers, thus increases both the 'truckmixer provision on site' time and the 'pour time'. (4) Poor estimation of the time interval between consecutive truckmixers arrivals causes truckmixers to queue on site or causes no concrete on site, which is a result of incorrect estimation of unloading time at the placing site.

- Problems (2) and (3) in the above paragraph can be grouped as 'miscellaneous waiting time'. It does affect the performance of matching. Table 2 shows that the 'miscellaneous waiting time' wastes more than 3 minutes on average for each truckmixer. Problems (1) and (4) above occur due to poor time interval estimated for consecutive truckmixers. The wrong time interval increases both 'truckmixer provision on site' time and 'pour time' and hence worsen the performance of matching. 60% respondents agree that to correctly specify the time interval between consecutive truckmixer arrivals when they put their orders for concrete supply, experience in estimating the time is important.

  Table 2 shows the finding of 'no availability of concrete on site', 'miscellaneous waiting time', 'truckmixer queuing time on site' and 'washing out plus waiting time' in the survey, which are quite similar to the finding of Anson *et al.* (2002). It proves that there is a good chance that both this and the previous findings are realistic.

- It is suggested that the batching plant should adjust the 'start loading concrete' times to suit the actual unloading times of truckmixers on site.

  Start loading concrete time at plant for a truckmixer is a function of four factors:

  = f(journey distance, queuing time, miscellaneous waiting time, truckmixer inter-arrival time)

  The effects of the first two factors can be obtained from previous statistical data (Anson *et al*., 2002). The third factor 'miscellaneous waiting time' is a factor which wastes about 3 minutes (see Table 2) in the whole supplying operation. So, an adjustment to the 'start loading concrete' time is necessary. For example, when a batching plant schedules to start loading a batch of concrete onto a truckmixer for delivery at 8:30am, and in order to avoid the 3 minutes wastage of 'miscellaneous waiting time' on site, the plant should start loading concrete onto the truckmixer at 8:33am.

- The truckmixers inter-arrival time (or time interval between consecutive truckmixers) is a function of two factors:

  Truckmixers inter-arrival time = f(truckmixer volume, placing method)

  The effects of these two factors can be obtained from Anson *et al*. (2002) too. Tables 3 and 4 reproduces with modification the mean truckmixer unloading times for different site placing methods and different volumes of truckermixer used from that paper. The following shows examples of estimating truckmixers inter-arrival time:
  1. Inter-arrival time for a pour using Hoist and Barrow for unloading concrete and using specified 7 m^3 truckmixers is 46.2 minutes (Table 3).
  2. Inter-arrival time for a pour using pump for unloading concrete and using unspecified volume of truckmixers is 18.3 minutes (Table 3).
  3. Inter-arrival time for a pour using crane (but unknown number of skips) and using specified 5m^3 volume of truckmixers is 22.0 minutes (Table 4).

Table 3: Mean truckmixer unloading times for different site placing methods and different volumes of truckmixers used

Placing Method		Volume of concrete carried (m^3)	No. of trips (Anson *et al.*, 2002)	Unloading time (min)	Unloading time for no specified volume of truckmixer (min)
				Mean	Mean
Crane	**1 skip**	**5 or less**	196	23.8	(196*23.8+140*27.6)/(196+140) = 25.4
		7	140	27.6	
	2 skips	**5 or less**	374	21.0	(374*21+423*25.2)/(374+423) = 23.2
		7	423	25.2	
Pump		**5 or less**	101	16.2	(101*16.2+104*20.3)/(101+104) = 18.3
		7	104	20.3	
Hoist and Barrow		**5 or less**	51	29.3	(51*29.3+31*46.2)/(51+31) = 35.7
		7	31	46.2	
Direct tip		**5 or less**	146	8.5	(146*8.5+48*11.1)/(146+48) = 9.1
		7	48	11.1	
Backhoe		**5 or less**	39	15.2	(39*15.2+24*18.8)/(39+24) = 16.6
		7	24	18.8	
Total number of trips			1677		

Table 4: Mean truckmixer unloading times for crane placing method with unknown number of skips

Volume of concrete carried (m^3)	Unloading time (min)	Unloading time for no specified volume of truckmixer (min)
5 or less	(196*23.8+374*21)/(196+374) = 22.0	(196*23.8+374*21+140*27.6+423*25.2) / (196+374+140+423) =23.9
7	(140*27.6+423*25.2)/(140+423) = 25.8	

Note: the calculations in this table are based on the data in Table 3 for cranes.

4. Conclusion

1. Fifty-one respondents from the recent questionnaire survey generally agree on the fact that the performance of suppliers (concrete batching plant) is better than that of their clients (construction sites).

2. Truckmixers idly queuing on site is usually observed. To improve such unsatisfactory situation, the concrete plant should adjust its 'start loading concrete' time (i.e. GenT in the **RMCSIM** computer simulation program (Tang *et al.*, 2003)). From the survey finding, 3 minutes caused by 'miscellaneous waiting time' is suggested to be added to the originally scheduled 'start loading concrete' time (or GenT) at the plant.

3. After adjusting the 3 minutes 'miscellaneous waiting time' by delaying the 'load concrete time' at the concrete plant, the 'idle time on site' per trip of truckmixers should be reduced by 3 minutes on average. It can be estimated that the queuing time on site will decrease by 22% (i.e. [(13.6 - 10.6) /

13.6]*100%}. 13.6 has been taken instead of 11.67 (see Table 2) in the calculation in order to have a more conservative (or safer) estimation.

4. Inter-arrival time between consecutive truckmixers can be more accurately estimated by considering the truckmixer volume and the placing method. Further investigation work can be that adjusted GenT values and a more accurate value of inter-arrival time for a pour, based on the data of Tables 3 or 4, be used as inputs for running the simulation model **RMCSIM** to see whether or not the new simulation result would have improvement on concrete delivery operations.

5. References

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Appendix: Examples of analysis of the survey data using the 'Relative Importance Index' technique

Performance of concrete batching plant and sites	Strongly Disagree	Disagree	Neutral/ Don't know	Agree	Strongly Agree	**Relative Importance Index**
	(1)	(2)	(3)	(4)	(5)	
1. Booking is usually successfully entertained by the plant.	0	0	4	47	0	0.784
2. Grading of concrete is usually satisfactory.	0	0	3	45	3	0.800
3. Delivery of concrete is usually on schedule.	0	14	18	19	0	0.620
4. The performance of truckmixer delivery is good in general.	0	9	16	25	1	0.671
5. Placing site is usually not ready when the truckmixer comes.	0	9	18	24	0	0.659
			(Scores)			

Note: $[(1 \times 0 + 2 \times 0 + 3 \times 4 + 4 \times 47 + 5 \times 0) / 5] / 51 = 0.784$
$[(1 \times 0 + 2 \times 0 + 3 \times 3 + 4 \times 45 + 5 \times 3) / 5] / 51 = 0.800$