Productivity of Ready Mixed Concrete Placing in Singapore

SHOU QING WANG, GEORGE OFORI and CHENG LIAN TEO

Abstract

Ready mixed concrete (RMC) placing is a major on-going operation on construction projects in many countries. This is particularly true of the big city of Singapore where huge re-housing and development programs call for vast quantities of concrete while many building sites in the city are very short of space and there is simply no room for a site-batching plant and stockpiles of aggregates and storage of cement. Concrete must be batched remotely and delivered to sites by truckmixers. The productivity of RMC placing is therefore of great importance to the productivity improvement of the whole construction industry of each country.

This paper reports on a study undertaken at the end of 1999 on the productivity and utilization of labor and equipment resources in the placing of in-situ RMC in Singapore. The study involved close observation of 32 pours on building sites, each from its beginning to end. Much detailed productivity information was derived and different concrete placing methods were compared. Factors affecting the RMC placing performance were also studied. Benchmarks, which describe the current state of RMC placing in Singapore were produced not only for measuring progress of RMC placing productivity over time but also for making comparisons with other large cities.

Keywords: Productivity, Ready mixed concrete placing, Construction, Singapore.

Introduction

By the traditional definition of ‘construction’, which focuses mainly on on-site construction activities, the construction industry accounted for about 9.1% of Singapore’s nominal GDP in 1998 (Department of Statistics, 1998). Although this is comparatively lower than other sectors, the construction industry’s close links with other industries make it a significant sector in the national economy (CIDB, 1998).

Concrete placing is a massive operation in the construction industries of many countries. Chan and Kumaraswamy (1995) found that the operational productivity of equipment, concrete placing and labor in various trades was ‘an essential intrinsic parameter also influencing the construction duration’. Anson et al (1986) also illustrated the importance of the concreting industry, especially the ready mixed concrete (RMC) industry with the use of the production of RMC given in per capita per annum. The RMC industry has always played an important supportive role in the growth of the construction industry and this is also true in Singapore.

The early construction industry of Singapore relied on samsui women for hauling concrete and bricks. The concrete industry has come a long way since the time when the concrete required was mostly site mixed and contractors were reluctant to use RMC. Today in Singapore, the majority of the buildings are constructed of reinforced concrete. Of these projects, almost 100% of concrete required is supplied ready-mixed from off-site batching plants. The use of site-batched concrete is practically nil and is restricted to small jobs where their quantity required would not justify an order from the RMC suppliers.

Many buildings in Singapore are still constructed using the traditional method of in-situ concrete placing. Only in a few tall office buildings or where time is a vital factor, are steel elements used. Moreover, although prefabrication has been actively promoted and supported by the then Construction Industry Development Board (CIDB), now the Building and Construction Authority (BCA), since the mid-1980s, and the technology has been introduced in the construction industry for some time, it has not been widely used. The present usage of prefabricated components is only 6% (Construction 21
The construction industry in Singapore has always been known to have relatively low productivity when compared with its counterparts in many industrialized countries (Construction 21 Steering Committee, 1999). Despite many attempts by the then CIDB, and many other governmental and professional organizations to improve productivity, the rate of growth of construction productivity is still below Singapore’s national average.

Perhaps the two most important problems of the local construction industry are its declining rate of productivity increases and its lack of productivity standards or benchmarks. Many research studies undertaken in Singapore have dealt mainly with the overall aspect of productivity improvements of the industry. Not many detailed studies have been carried out on either a major construction operation or trade. Despite the increasing use of precast elements and structural steel components, the construction industry still relies heavily on on-site RMC placing.

Since the construction industry will continue to be a significant sector in Singapore’s economy, the study of the productivity and utilization of the resources in the RMC industry, especially RMC placing, is fundamental to the construction industry. Thus, it is pertinent to study the factors which influence the productivity of RMC placing. The results can provide insights into areas of enhancement of the productivity of the production and placing of RMC. The results can also serve as benchmarks for local contractors to enhance their productivity and facilitate the comparison of the performance of the local RMC industry with those of other countries or cities (Wang and Anson, 2000).

### Table 1. Demand for Ready Mixed Concrete In Singapore

<table>
<thead>
<tr>
<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>RMC (10^3m³)</td>
<td>4,666.6</td>
<td>5,517.2</td>
<td>6,768.6</td>
<td>7,776.7</td>
<td>8,274.7</td>
<td>10,064.9</td>
<td>11,535.1</td>
<td>10,643.5</td>
</tr>
</tbody>
</table>

Source: CIDB (1998)

RMC Industry in Singapore

Initially, local contractors were not receptive to the use of RMC. The first RMC batching plant was established in 1950 by Hume Industries (Far East) Ltd. It was subsequently shut down and taken over by Swee Construction Company Pte Ltd. In 1958, Concrete (Premix) Pte Ltd was set up by Swee Construction Company Pte Ltd, which supplied RMC to the projects of two of the major public-sector client agencies, the Public Works Department and the Port of Singapore Authority, thus reviving the RMC industry. The plant expanded in operation after orders were received from the private sector. The RMC industry saw a new entrant in 1967 when the Malayan Rock Product Pte Ltd extended its RMC business from Malaya to Singapore. Between 1969 and 1970, Island Concrete Pte Ltd and Wheel-On-Ready-Mix Company Pte Ltd were established. Altogether, the four batching plants produced about 200,000 m³ of RMC each year.

Subsequently, more RMC companies were established. They were Lee Hung Cheng Granite Quarry Co Pte Ltd, Tru-mix Concrete Pte Ltd and Ideal Concrete Pte Ltd. The number of RMC companies increased to about twelve in 1978 and the industry produced almost 1,200,000 m³ of RMC from 1971 to 1978. According to Mr Lim Hoe Peng, Executive Secretary of the Ready Mixed Concrete Association of Singapore (RMCAS), there are currently 17 RMC companies registered with the RMCAS and about 100 batching plants in Singapore (there are also 7 RMC companies un-registered with RMCAS). The big players in the RMC industry include Supermix Concrete Pte Ltd, Sembawang Resources Ltd, Island Concrete Pte Ltd and Eastern Concrete Pte Ltd.

From Table 1, it can be seen that the demand for RMC has been rising steadily over the years from 1991 to 1998, though a slight decline of 8.4% was observed in 1998. This decline was due largely to the effects of the Asian financial crisis that caused many developers to put on hold some building projects. However, with the outlook of an early economic recovery, the RMC
industry can look forward to increased demand in the future. Given the total population in Singapore in 1998 of 3,865,600 (Department of Statistics, 1998), this would give a production of 2.75 m³ of RMC per capita in 1998, which is unusually high when compared with other countries.

The level of usage of structural steel construction in Singapore is not known, but it is understood that its use is not widespread. Also, since the present usage of prefabricated components is only 6%, as mentioned above, it can be safely concluded that the traditional in-situ construction will continue to be widely adopted by contractors. Hence, the study of RMC placing is important to improve not only the productivity of the concreting industry but also that of the construction industry as a whole.

Research Objectives

RMC is arguably the dominant construction material and RMC placing is one of the most significant on-going major construction operations in Singapore. However, the productivity of RMC placing in Singapore is not known. This makes it impossible to determine where and how to improve it. There is no published local information on the productivity levels and utilization of the RMC placing equipment, labor and truckmixer (TM) in either a typical concreting pour or the overall operation. By determining the productivities and the utilization levels of these resources, the site and batching plant personnel can have better control over these resources and thus improve the efficiency with which they employ these resources. In particular, during a typical RMC placing, the scheduling of truckmixers is a significant issue. The matching of RMC supply to the site need is necessary to improve the overall concreting productivity (Anson and Wang, 1998). This research study, being the pilot of a bigger one, can also facilitate future work on establishing the industry-wide RMC placing benchmarks and simulating the effect of truckmixers’ arrival patterns on the placing productivity which will assist contractors and batching plant personnel in better scheduling the truckmixers as well as in simulating the provision and operation of the entire RMC industry so as to improve the overall productivity.

The main objective of this pilot study is to measure the productivities and utilization level of site labor, equipment and truckmixers employed in the RMC placing on building projects in Singapore, which can be formulated as a basis of performance benchmarks for local contractors to target at in improving their RMC placing productivity. These data can also be used for the purpose of comparing Singapore’s performance with those of other countries or cities. The study can also provide better understanding of the factors affecting the RMC placing productivity, and provide guidance on the areas where the productivity can be improved (at both site and industry levels) and how it can be improved.

Research Methodology and Scope

The method adopted for this study was as follows:

- Site observations of 32 pours on five construction sites whereby each pour was observed from beginning to end;
- Field visits to eight RMC batching plants to obtain better understanding of the whole RMC industry operation; and
- Interviews with various practitioners in the industry on various aspects of the subject.

The study concentrated on pours for buildings only where RMC placing was currently being carried out at the lower floors (underground to fifth floor), excluding civil engineering pours though the inclusion of the latter would be a more accurate representation of RMC pours but, according to Anson et al (1996) and Wang (1995), there should be no significant difference in the results.

Previous Work

Extensive studies have been carried out on the topic of construction productivity improvements but only a few focused on the RMC industry in the country. For example, Chang (1996) explored the feasibility of applying the Just-In-Time concept to improve productivity in the off-site prefabrication of precast concrete components. A CIDB Construction Taskforce was set up in mid-1991 to consider the issue of low productivity in the local construction industry and to recommend ways to improve productivity in the immediate and long term (CIDB, 1992). The Taskforce
identified several measures to improve construction productivity as reducing manpower usage on site and promoting the use of prefabricated components and RMC.

A recent comprehensive study jointly spearheaded by the Ministry of Manpower and Ministry of National Development (Construction 21 Steering Committee, 1999) highlighted that the most pressing issue confronting the construction industry is its low productivity level. It attributed the causes to the heavy reliance on unskilled foreign workers, a multi-layered subcontracting system involving many small firms, and segregation of activities on construction projects. To enhance productivity, the Construction 21 Committee identified the necessity of improvements in areas of buildability (including the use of prefabrication and RMC), construction safety, maintainability, quality, research and development, construction management, foreign worker management, and procurement practices which permit and promote integration of the efforts of project participants. Therefore, a study of the local RMC industry especially the RMC placing is necessary and useful. Furthermore, as RMC placing is a major on-going operation in Singapore, the study of the productivities, utilization of the various resources, and the simulation of truckmixer scheduling and modeling of the entire industry can contribute to construction productivity improvement.

In contrast to the situation in Singapore, there have been studies on the RMC industry in other countries. For example, Kieffer and Selby (1983) found that the RMC placing productivity achieved depends on many factors such as the reliability of the concrete supply, placing equipment, placing gang and size and shape of the pour. They measured the productivities of two main components: placing equipment and crew involved. Placing rates of transport equipment were ascertained as the ratio of the quantity of concrete to the time spent in transporting it. Labor productivity was taken as the relationship between the quantity of concrete placed and the crew time spent between the arrival of the first concrete at the site and the placing of the last concrete in the formwork. Those included in the crew were equipment operators and helpers, men directing trucks or loading buckets and the actual placing gang. Non-working foremen and truckmixer drivers were however excluded from the definition of the crew. Delay rates were also measured for truckmixers, placing equipment and crew expressed as a percentage in terms of the delay times in minutes per hour.

In a study by Anson et al. (1986) to find out why concrete pumping was less common in the United Kingdom than in the then West Germany and why the use of crane and skip was more commonly used in the former than in the latter, differences in practice and performance of the concreting industry between the two countries were examined. Placing rates were measured for the two countries as the ratio of the quantity of concrete placed to the time between the arrival of the first truckmixer at and the departure of the last truckmixer from the site. They reasoned that this would not take into consideration delay times resulting from incomplete preparation by the contractor or the late arrival of the first truckmixer. Their calculation of placing rates would give placing rates once pumping and lifting of the skip has begun. Several types of delays in concreting between the two countries were also found. Delays measured for pumped pours were average delays as a percentage of total pour time, number of pours involving delays as a percentage of total pours and number of pours with delays over 10% as a percentage of total pours. Delays measured for craned and skipped pours were average delays due to concrete delivery as a percentage of total pour time for craned and skipped pours. Delays attributable to the RMC supplier and those attributable to the contractor were also distinguished.

Later studies by Anson et al. (1996) and Wang (1995) employed different yardsticks for measuring the productivity of the RMC placing of Hong Kong and Beijing buildings. Placing labor or equipment productivities were given as the ratio between the quantity of concrete to the man-hours (mh) or equipment-hours (eh) committed by the placing gang or equipment. Truckmixer productivity was the relationship between the quantity of concrete carried divided by the truckmixer-hours (th) spent on site. Intrinsic productivities were also measured for labor, equipment and truckmixer to illustrate the productivities that would be achieved if there were no delays due to smooth supply of concrete or any other factors. Production data expressed as a percentage of pour time for labor active time, equipment active time, equipment fault or diverted time, time of no concrete on site and time of other delays were also derived.

The study conducted in Singapore to measure the productivity of concreting of building pours is similar in many aspects to the one undertaken by Anson et al. (1996) and Wang (1995). Thus, the results indicating the features and performance of the RMC industry in
Singapore can be compared with those found in the studies in other countries or cities.

**Characteristics of Pours Observed and Usage of Placing Resources**

Of the 32 pours observed in this study, 10 pours were pumped, 6 tremied, and 16 craned and skipped (skipped). The pumped pours were all accomplished using mobile pumps. All tremied pours were of tremied piles. For the skipped pours, the capacity of each skip is 1 m³. Table 2 summarizes the characteristics of each pour observed and the placing resources committed. It includes placing method employed, type of pour, quantity of concrete placed, overall pour time between booked start and departure of the last truckmixer from the discharge point, total time of delays caused by truckmixers when there is no concrete on site (beginning from the booked start to end of pour), total time of other delays, time spent by truckmixer on site, duration of usage of placing equipment and lastly the man-hours committed by the placing gang, site personnel receiving and unloading truckmixers, and truckmixer driver on site.

Placing operations using crane and skip were usually of small pours whereas the pump was used for large ones. The smallest pour size in the sample was 5 m³ and it was undertaken with the aid of crane and skip. Although the average pour duration was 3.74 hours, an average of 5.5 hours (or 153.7% of pour duration as shown in Table 3) was spent on site by truckmixers. Despite this, there was still an average period of 42.9 minutes (accounting for 20% of pour duration) when concreting was interrupted, waiting for the arrival of truckmixers (RMC).

For each pour, the time spent by truckmixers in queuing, unloading, and washing out was also recorded (Table 3). A truckmixer spent a total time of 34.2 minutes on an average pour. Of the average 34.2 minutes truckmixer time on site, a typical 60.2% of the time was spent unloading concrete, 23.1% queuing on site and 16.7% washing out and leaving site. It is pertinent to note that truckmixers were idle over 200% of pour time for pumped pours and this indicated the mismatching of RMC supply to site requirement. Given that the total number of truckmixers in the industry is limited, this will affect the RMC supply to other sites and also result in the low utilization of truckmixers.

<table>
<thead>
<tr>
<th>Placing Method</th>
<th>No. of Pours</th>
<th>Pour Size (m³)</th>
<th>Pour Time (h)</th>
<th>No TM on Site (min.)</th>
<th>Other Delays (min.)</th>
<th>Man Hours (mh)</th>
<th>Equipment Hours (eh)</th>
<th>Truckmixer Hours (th)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skipped slab &amp; beam</td>
<td>10</td>
<td>22.5</td>
<td>3.43</td>
<td>44.2</td>
<td>25.3</td>
<td>38.3</td>
<td>3.2</td>
<td>2.6</td>
</tr>
<tr>
<td>Skipped wall &amp; column</td>
<td>6</td>
<td>26.3</td>
<td>2.95</td>
<td>20.0</td>
<td>19.3</td>
<td>15.9</td>
<td>3.0</td>
<td>3.2</td>
</tr>
<tr>
<td>All skipped</td>
<td>16</td>
<td>23.9</td>
<td>3.25</td>
<td>35.1</td>
<td>23.1</td>
<td>29.9</td>
<td>3.1</td>
<td>2.8</td>
</tr>
<tr>
<td>Tremied pile</td>
<td>6</td>
<td>16.8</td>
<td>1.01</td>
<td>27.5</td>
<td>17.2</td>
<td>4.9</td>
<td>1.2</td>
<td>1.0</td>
</tr>
<tr>
<td>Pumped slab &amp; beam</td>
<td>10</td>
<td>149.9</td>
<td>6.16</td>
<td>64.7</td>
<td>71.9</td>
<td>69.3</td>
<td>6.2</td>
<td>12.4</td>
</tr>
<tr>
<td>All</td>
<td>32</td>
<td>61.9</td>
<td>3.74</td>
<td>42.9</td>
<td>37.2</td>
<td>37.5</td>
<td>3.7</td>
<td>5.5</td>
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</table>

<table>
<thead>
<tr>
<th>Placing Method</th>
<th>No. of Pours</th>
<th>Pour Size (m³)</th>
<th>Pour Time (h)</th>
<th>No TM on Site (%)</th>
<th>Have TM on Site (%)</th>
<th>TM Time on Site (min.)</th>
<th>% of TM Time on Site</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skipped slab &amp; beam</td>
<td>10</td>
<td>22.5</td>
<td>3.43</td>
<td>17.7</td>
<td>140.4</td>
<td>43.7</td>
<td>4.0</td>
</tr>
<tr>
<td>Skipped wall &amp; column</td>
<td>6</td>
<td>26.3</td>
<td>2.95</td>
<td>12.3</td>
<td>105.4</td>
<td>40.8</td>
<td>16.5</td>
</tr>
<tr>
<td>All skipped</td>
<td>16</td>
<td>23.9</td>
<td>3.25</td>
<td>15.7</td>
<td>127.3</td>
<td>42.6</td>
<td>8.7</td>
</tr>
<tr>
<td>Tremied</td>
<td>6</td>
<td>16.8</td>
<td>1.01</td>
<td>40.3</td>
<td>120.6</td>
<td>20.8</td>
<td>33.2</td>
</tr>
<tr>
<td>Pumped slab &amp; beam</td>
<td>10</td>
<td>149.9</td>
<td>6.16</td>
<td>16.1</td>
<td>215.7</td>
<td>28.8</td>
<td>40.2</td>
</tr>
<tr>
<td>All</td>
<td>32</td>
<td>61.9</td>
<td>3.74</td>
<td>20.4</td>
<td>153.7</td>
<td>34.2</td>
<td>23.1</td>
</tr>
</tbody>
</table>
Anson et al (1996) and Wang (1995) highlighted that the utilization of the resource expressed as active time percentage of total pour time is also a useful measure of the RMC placing productivity. Table 4 summarizes the average production data for the three placing methods. This is useful especially for site management personnel to know the utilization of the different resources on the RMC placing operation. From this knowledge, they can readjust or reallocate the resources and carry out better site planning so as to achieve a higher efficiency on the operation performed.

The average production time of equipment and labor at 73.8% and 79.7% of pour time were very close to the findings of Wang and Anson (2000) who from their study of 154 pours in Hong Kong and 34 in Beijing, observed the productivity levels to be 73.8% and 80.3% respectively in Hong Kong, and 71.1% and 78.4% respectively in Beijing. However, a note of caution is to be observed in commenting that the productivities of resources in concreting in Singapore are similar to those in Hong Kong as the sample size here is only 32 pours whereas that of Hong Kong was 154 pours. Furthermore, the study by Anson et al (1996) included the placing method by hoist and barrows, which was excluded in this sample as local contractors no longer practice this method.

The last but one column of Table 4 measures delays caused by the RMC supplier. Anson et al (1986) stressed that it is important to differentiate between delays caused by the concrete supplier and those caused by the contractor. They reasoned that the contractor is responsible if there is a miscalculation of the quantity of concrete required which resulted in a wait for the final truckload. These delays should be classified under contractor delays and not supplier delays.

The average delay due to concrete supply as a percentage of pour time for skipped pours at 15.7% in Singapore was higher than the figures for United Kingdom, West Germany, Hong Kong and Beijing at 10%, 7%, 11% and 14.2% respectively (Anson et al, 1986, 1996; Anson and Wang, 1998; Wang, 1995; Wang and Anson, 2000). The use of crane and skip is not as widely practiced by local contractors as their foreign counterparts. Hence, this may lead to overestimating of the delivery intervals by the batching plants. For the pumped pours, the delay figure of 16.1% measured was also higher than the West Germany and Hong Kong rates, both of which were about 11% but close to Beijing’s figure of 16.3% and lower than the United Kingdom’s 23%. Poor coordination between the United Kingdom contractors and the concrete supplier was responsible for this late delivery of concrete.

### Productivity of RMC Placing

Productivity measurement is a useful tool for analyzing the changes in productivity of an operation over time. The use of productivity measurements as a standard or benchmark will help to gauge efficiency and the formulation of effective and constructive initiatives to improve the allocation and utilization of resources in RMC placing.

Labor is the most common factor used in measuring productivity especially in building works but rarely is labor work independent of some type of equipment. There are several methods that may be used for a concreting operation; some are more labor intensive while others are more equipment intensive. For this reason, it makes good sense to monitor both the productivities of labor and equipment. In addition, since this study is not independent of truckmixers, productivity measurement, was carried out for all these three key RMC placing resources: truckmixer, equipment and labor.

As mentioned above, the productivity achieved by a truckmixer in this study is given by the ratio between RMC finally in position (pour size) and time spent by the truckmixer on site. For placing equipment, it is the ratio between pour size and time committed by the equipment on site for the placing operation. It excludes

<table>
<thead>
<tr>
<th>Placing Method</th>
<th>Equipment Active</th>
<th>Labor Active</th>
<th>Truckmixer Idle on Site</th>
<th>Waiting for Truckmixer</th>
<th>Other Delays</th>
</tr>
</thead>
<tbody>
<tr>
<td>All skipped</td>
<td>86.0</td>
<td>87.4</td>
<td>38.8</td>
<td>15.7</td>
<td>8.1</td>
</tr>
<tr>
<td>Tremied pile</td>
<td>34.5</td>
<td>31.9</td>
<td>49.9</td>
<td>40.3</td>
<td>27.9</td>
</tr>
<tr>
<td>Pumped slab &amp; beam</td>
<td>64.1</td>
<td>86.6</td>
<td>207.4</td>
<td>16.1</td>
<td>20.8</td>
</tr>
<tr>
<td>All Methods</td>
<td>73.8</td>
<td>79.7</td>
<td>89.9</td>
<td>20.4</td>
<td>16.4</td>
</tr>
</tbody>
</table>
Productivity of Ready Mixed Concrete Placing in Singapore

For labor, productivity is the ratio between pour size and time committed by the concreting gang. Table 5 summarizes these productivities for the 32 pours studied.

From Table 5, the pumped pours were the fastest, averaging 24.9 m³/h or 25.0 m³/eh which is a little higher than the tremied 21.6 m³/h or 19.3 m³/eh and three times the skipped 7.4 m³/h or 7.8 m³/eh. Truckmixer productivity was however the highest for tremied pours at an average of 19.5 m³/th as unloading in this method took only a few minutes, followed by pumped pours at 13.7 m³/th. Productivity of truckmixer for skipped pours was roughly half of other pours due to the longer time spent by the truckmixer on site. Labor productivity was the highest for tremied pours at 4.0 m³/mh, as fewer workers are required for this method. Pumping which is a preferred placing method by local contractors had the next highest labor productivity of 2.2 m³/mh. Again, the skipped labor productivity is the lowest, at only 1.0 m³/mh.

Intrinsic performance measures performance that would hypothetically have been achieved if there were no interruptions to the supply of concrete, and no other delays due to placing equipment problems or poor pour preparation. Instead of placing at average 15.5 m³/h overall with labor and equipment productivities at 1.9 m³/mh and 15.3 m³/eh, better intrinsic performance at 27.8 m³/h, 6.1 m³/mh and 29.6 m³/eh would be achieved. The difference between the measured and intrinsic performance shows the potential for improving the placing productivity if unnecessary interruptions during RMC placing are eliminated.

Table 6 gives the distribution of placing rates for the three different placing equipment. Together with Table 5, it provides helpful information to a contractor when deciding on a placing method for a major concreting operation. Specially designed for concrete placing, a pump has a comparatively higher placing rate and it should be used whenever practicable if the contractor wants to achieve a high placing rate for all types of pours at various heights. Similar details of labor productivity are shown in Table 7.

Matching of Concrete Supply to Site Requirement

As mentioned by Anson and Wang (1998) and Wang (1995), timely supply of RMC to the site is a major factor affecting productivity of concreting operations. The RMC supplier should provide a continuous flow of concrete to the site to ensure that there are no interruptions to the placing operation. However, the

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Table 5. Key Parameters of Productivity Achieved

<table>
<thead>
<tr>
<th>Placing Method</th>
<th>No. of Pours</th>
<th>Pour Size (m³)</th>
<th>Measured Placing Rate</th>
<th>Intrinsic Placing Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Overall (m³/h)</td>
<td>Labor (m³/mh)</td>
</tr>
<tr>
<td>Skipped slab &amp; beam</td>
<td>10</td>
<td>22.5</td>
<td>6.7</td>
<td>0.6</td>
</tr>
<tr>
<td>Skipped wall &amp; column</td>
<td>6</td>
<td>26.3</td>
<td>8.6</td>
<td>1.6</td>
</tr>
<tr>
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<td>16</td>
<td>23.9</td>
<td>7.4</td>
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<td>Tremied pile</td>
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<td>21.6</td>
<td>4.0</td>
</tr>
<tr>
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<td>10</td>
<td>149.9</td>
<td>24.9</td>
<td>2.2</td>
</tr>
<tr>
<td>All</td>
<td>32</td>
<td>61.9</td>
<td>15.5</td>
<td>1.9</td>
</tr>
</tbody>
</table>

Table 6. Distribution of Placing Rates of Equipment

<table>
<thead>
<tr>
<th>Placing Method</th>
<th>No. of Pours</th>
<th>m³/eh</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>0.00~ 9.99</td>
</tr>
<tr>
<td>Skipped</td>
<td>16</td>
<td>15</td>
</tr>
<tr>
<td>Tremied</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>Pumped</td>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td>All</td>
<td>32</td>
<td>16</td>
</tr>
</tbody>
</table>
facts that a limited number of truckmixers is available to the industry as a whole and that each batching plant is supplying several sites on any particular day, make an uninterrupted supply impossible to achieve in general. Variability in traffic conditions and the fact that concrete must be reasonably fresh at the time of placing are also relevant factors. For example, in only seven out of the 154 pours they studied in Hong Kong was an uninterrupted supply of concrete actually achieved.

In the 32 pours studied in Singapore, on only four pours was there an uninterrupted supply of concrete. Although truckmixers were present on site for only 79.4% of pour time, the actual provision of truckmixer-hours, a measure of the level of RMC service, was generally much greater than the number of hours of pour duration. The RMC companies actually provided 21.6 truckmixer-hours on site (i.e., not including traveling and staying batching plant time) for every 10 hours of pumped pour duration. The corresponding figures for craned and tremied pours were 12.7 and 12.0 truckmixer-hours (Table 3).

As mentioned before, typically 20.4% of pour time was spent waiting for concrete in the 32 pours (Table 3) while the mean time spent in waiting for arrival of truckmixers was 42.9 minutes (Table 2). Based on the data collected, although about one third of the sample had waiting times less than 20 minutes, there is a cause for concern as nearly one fifth of the pours had waiting times exceeding one hour. Despite this, the mean idle time of truckmixers on a pour was 89.9% of pour time (Table 4). This idle time includes the time spent queuing on site by truckmixers and time not spent efficiently in discharging concrete. It excludes time for washing out and leaving the site.

Figure 1 shows, for each pour, the truckmixer-hour provision on site, as a percentage of pour time, plotted against the interruption to concrete supply, also as a percentage of pour time. This illustrates the difficulty experienced in matching concrete supply to site requirement, discussed previously.

If a “good” match of concrete supply to site requirement were fixed arbitrarily as a truckmixer-hour provision of between 100% and 150% of pour time and an interruption in supply of not more than 10% of pour time, as indicated by the boxed area on Figure 1, only three cases of the 32 pours would lie in the box while the majority would fall outside it. The poor match is unhelpful to contractors when waiting times are long and unhelpful to concrete suppliers when truckmixers are standing idle in queues on site. The productivity of concreting of both the site and supplier will be significantly improved if a larger percentage of pours falls within the box.

The concept embodied in Figure 1 could be developed as a useful benchmark that describes the extent to which the RMC supply matches the site requirement. The productivity of concreting ought to be enhanced (a much higher percentage of pours would fit into the box) if the productivities of the site and the RMC supplier are seen as a combination. The site contractor is probably not over-concerned with a high truckmixer provision, but the RMC supplier is interested in both of the service aspects portrayed. RMC companies try to avoid excessive gaps in the supply of concrete in order to maintain their reputation for reliability and will often back up two or three truckmixers on site.
and sometimes more. What constitutes an “excessive” gap depends on several factors, including the importance of the pour (which usually equates to the size of pour), the placing method, and the degree of urgency communicated by the site. Taking these factors into account, as well as the distance involved, likely traffic conditions, and the other commitments that day, the RMC supplier assigns a certain number of truckmixers to a site. A simulation model to find the optimum number of truckmixers that should be dispatched by a batching plant to reduce both the site waiting times and truckmixer idling times on site would be useful. This model would be of immense value if extended to the whole RMC industry in a city.

Improving the RMC Placing Productivity

Based on this study, some recommendations for improving the RMC placing productivity in Singapore, in addition to the choice of a suitable placing method according to the schedule required, type of pour, availability of equipment etc., and the effective coordination with RMC supplier and full preparation for the pours, are now presented.

- **Truckmixer:** Where the truckmixer is to be located for discharging should be planned well in advance. Space should be enough for truckmixers to maneuver easily as the time taken to change over truckmixers for unloading is significant in the overall efficiency of the placing operation. Ideally the replacement truckmixer should be in position before the proceeding one has completed its discharge.

- **Placing Equipment:** The method of placing should be commensurate with the quantity of concrete to be placed. The crane should employ a larger skip if it is available, say using 2 m³ instead of 1 m³, so that the filling, discharging and slewing time is reduced to a minimum. The use of multiple skips is also relevant so that when one skip is being lifted, the other is being filled. For long pours, the contractor should employ a concrete pump and, if applicable, use a mobile one because of its higher placing rate than a fixed pump as no re-adjustment of pipelines for the mobile pump is needed (Anson *et al.*, 1996). For underground pours, tremie is usually a reasonable choice.

- **Placing Labor:** The size of the concreting gang should be adequate to place concrete at a speed that matches the output of the placing equipment. Long pours should be avoided since workers cannot perform well due to fatigue.

- **RMC Supplier:** The RMC supplier should improve on the delivery intervals of truckmixers to avoid delays on their part and yet avoid overprovision of truckmixers on site. RMC supply should be able to match the placing rate required. For pumped pours, greater coordination between RMC supplier, pump supplier and contractor is imperative.

- **Contractor:** The quantity of concrete required has to be determined as accurately as possible so that there would not be excessive or insufficient concrete especially for the last truckmixer. If concrete is not sufficient, additional orders have to be placed and the concreting gang and equipment would be idle waiting for the arrival of the newly ordered truckmixers. Timing of orders for RMC should be such that there is a continuous flow of concrete for placing. If any delays occur, the contractor should inform the RMC supplier immediately so that he can reorganize his batching plant operation and truckmixer schedule if necessary.

- **Government Institution and Professional Body:** Government institutions and professional bodies such as the BCA, Singapore Contractors Association Ltd and RMCAS should continue studies on RMC placing productivity and establish related benchmarks which set targets for average contractors to reach and in turn, help them to improve their concreting operations. With the benchmarks produced, it would also be helpful for the whole industry to identify areas for its productivity improvement over time and to make comparison with other countries or cities.

Conclusions

As the productivity of the construction industry in Singapore is still low while RMC placing is a dominant operation which contributes to the overall construction productivity, this study, which involved detailed observation of 32 pours on building sites, is significant. Based on the productivity data collected and analyzed, benchmarks of RMC placing in Singapore in late 1999 were established which can serve as a basis for future
industry-wide benchmarks. However, the number of pours observed was relatively small, due to time constraints. Furthermore, though all the pours observed were of low storey heights varying between the basement and the fifth level, the difference in storey heights of the 32 pours may affect the results but they were not taken into consideration. In addition, work-study is usually associated with the ‘Hawthorne Effect’. The presence of the authors during the site visits may induce the workers to change their working speed. Workers observed may respond to the attention given to them and increase their placing rate, giving a false picture of the true productivity.

Further research is recommended to fine-tune the productivity measurement by conducting more observations on various types of pours. The research would require the cooperation of a large number of contractors and RMC suppliers; and the support of government agencies and professional institutions. Industry-wide data can then be collected and industry-wide benchmarks established. In addition, simulation models covering both the site and batching aspects for the whole RMC industry in Singapore should be undertaken. The models could be derived from a comprehensive study into the scheduling of the truckmixers (RMC supply) to meet site requirements for one site only or for the whole RMC industry in Singapore so as to improve its overall productivity.

References


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