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An innovative concrete practice performance measurement towards environmental improvement in Malaysia

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An Innovative Concrete Practice Performance Measurement Towards Environmental Improvement in Malaysia

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Abstract—The environmental impact from the concrete construction industry is quite alarming. The industry is embarking into improving the concrete performance and exploring into alternative materials to reduce such impact. An area which is lacking is improvement in the quality of concrete practice itself. By having good concrete practice, a good quality concrete can be achieved. This paper proposed a performance measurement of concrete practice and applies the measurement to assess the quality of concrete practice for a concrete structure project in Malaysia.

Keywords—environmental impact; quality; concrete; concrete practice; performance measurement;

I. INTRODUCTION

Ever since its discovery as a construction material, concrete has been extensively used and has been the most favored material over others. Over the years, extensive research has taken place to improve the variable properties that the material inherits especially its strength and durability.

In the present condition, the world is facing with environmental issues whereby the global effect of environmental pollution contributed by various activities has led to an impact whereby the world's ecosystem may not be sustainable in the future. Construction industry, mainly those which involved concrete construction has been identified as one of the major contributors to such phenomena.

Realizing this major environmental impact, various actions has been undertaken and policies drawn to control the situation at source. However those actions cover more on the concrete production and alternative materials.

An important aspect which is lacking is the improvement on the concrete practice itself, rather than just the concrete quality. Good concrete practice will lead to good quality concrete. Good quality concrete means less maintenance cost such as concrete repairs, strengthening and demolition works which lessen future environmental impact.

The present concrete practice has been 'self centered' where each discipline only concentrate within its own specialization without provision of inter-phasing between the different disciplines. This has also been termed as the 'concrete process puzzle' [1]

II. CONCRETE CONSTRUCTION AND THE ENVIRONMENTAL ISSUES IN MALAYSIA

Construction is a very important sector contributing to Malaysian economic growth. The industry has consistently contributed 3 to 5 % of the National Gross Domestic Product or GDP for the last 20 years. [2]. Without doubt, being in a tropical country, concrete is the most desired construction material used.

Along the process from project inception to completion of the constructed concrete products, activities which affect the environment are bound to take place. The major environmental impacts can be summarized as follows:

1) Identification of land use for the project will lead to flora and fauna disruption which in turn lead to unbalanced ecosystem and thus global warming [2], [3]
2) Manufacture of cement and concrete will lead to CO₂ emission, consumption of raw material, large consumption of energy and production of solid waste [4]
3) Transportation of concrete to site will consume large energy and production of solid waste [5]
4) Construction of the concrete product will consume energy, affect air quality, water quality and excessive noise pollution [6]

To compare some statistics on environmental impact from construction industry in Malaysia; (a) Malaysia has the highest deforestation in Asia region [3] (b) The construction and demolition waste produced in Malaysia was 1.55 million metric tons in 1994 with China being the highest in the Asia region with 200 million metric tons for year 2005. [7]

Development cannot be stopped just for the purpose of conserving the environment. Thus the concrete construction industry has to be regulated in such a manner that these environmental issues can be managed. The Malaysian Government has imposed various Acts and procedures to regulate construction projects such as the Land Conservation Act 1965, Water Quality Act 1920, Environment Quality Regulation 1985, Environmental Impact Assessment (EIA), Environmental Management Plan (EMP) and many more associated acts. The effectiveness of these acts and procedures will very much depend on the enforcement by the responsible Ministry. [8], [9]
III. THE CONCRETE PRACTICE PROCESS

Being a material of large variability in its characteristics, concrete design, concrete production, and concrete construction need to possess the right quality ingredients to produce the desired quality concrete products. Concrete design, concrete production, and concrete construction are the three main components which constitute a concrete practice.

The processes involved in concrete practice are as shown in Fig. 1.

![Fig. 1: The Concrete Practice Processes](image)

The concrete practice consists of 2 main processes, i.e., design process and construction process. The design process involved designing the concrete structures to meet the strength and durability requirement. In doing so, the concrete grade, reinforcement strength, adequate sizes of structural components and sufficient cover to reinforcement to meet exposure condition and fire resistance requirement need to be satisfied. The output of the design process is the concrete structural drawings and the works specification. The design output serves as input to the construction process.

The construction process involved 2 main activities: the concrete production and construction works. The concrete will be produced based on the design requirement and specification. The construction works will be done based on the concrete structural drawings and specification.

Since the concrete production and the construction works depend on the design output, it is thus very important that the drawings and specification spell out exactly what is required. Measure to minimize and control the environmental impact during concrete production and concrete construction works shall also be addressed by the specification. [10]

IV. FORMULATING THE CONCRETE PRACTICE PERFORMANCE MEASUREMENT

From the above, it is concluded that the quality of concrete practice depends on quality of concrete design, quality of concrete production, and quality of construction. This can be represented by the following formula:

\[
\text{Concrete Practice Quality} = W_1 \times \text{Quality of Design} + W_2 \times \text{Quality of Concrete Production} + W_3 \times \text{Quality of Construction}
\]

W1, W2, and W3 are the weightages linking all the attributes. The total of weightages W1, W2, W3 is 1.0 (i.e., 100%). The values of W1, W2 and W3 range from 0 to 1.0 and depend on the quality practice of that particular country. For example in a developed country, the practice in design, concrete production, and construction may be of the same weightage because all conform strictly to certain quality procedures whilst in underdeveloped countries, the construction practices might be worse off than the design and concrete production for reasons of many unskilled workers. The values of W1, W2 and W3 will need to be established by that countries’ industry expert assessment.

The quality of design, concrete production, and construction must be measured against criteria that are acceptable to constitute a quality measurement. The ranges of values for these qualities are from 0 to 100, i.e., worst quality to the best quality. In addition, the measured quality shall be reduced by a reduction factor if it does not satisfy certain compliance requirement. For example, in a concrete production, one of the important factors is that the aggregate must be stored in a suitable manner so as to avoid segregation. If this quality factor can be measured or quantify, then this will be one of the measured quality of concrete production. Whatever the final measured quality of concrete production is, the 28-day strength needs to satisfy the strength requirement. If this is not achieved, then a reduction factor has to be applied to the measured quality of concrete production. What it means is that the quality of concrete production has reduced due to incompliance to the required quality attributes and this quality is further reduced due to incompliance to strength requirement.

Based on the explanation above, the complete formulation of concrete practice quality is as follows:

\[
Q_{\text{(concrete practice)}} = W_1 \times Q_{\text{(design)}} \times QRF_1 + W_2 \times Q_{\text{(concrete production)}} \times QRF_2 + W_3 \times Q_{\text{(construction)}} \times QRF_3
\]

Where

\[
Q_{\text{(concrete practice)}} = \text{Quality of Concrete Practice}
\]

\[
Q_{\text{(design)}} = \text{Measured quality of design}
\]

\[
Q_{\text{(concrete production)}} = \text{Measured quality of concrete production}
\]

\[
Q_{\text{(construction)}} = \text{Measured quality of construction}
\]

\[
QRF_1 = \text{Reduction factor for quality of design}
\]

\[
QRF_2 = \text{Reduction factor for quality of concrete production}
\]
A study is being conducted on the quality of concrete practice involving construction of a 13 storey concrete structures for an office complex in Kuala Lumpur, Malaysia. The study commenced from construction of the pile caps and to date the construction has progressed until level three.

Weightage for design, concrete production and construction have been measured throughout the construction works and data have been collected to identify the score for quality of concrete practice for the concrete works. This paper will report on the preliminary findings of the measured quality for Q\(_{\text{design}}\), Q\(_{\text{concrete production}}\) and Q\(_{\text{construction}}\). Further research is required to achieve these weightages. Q\(_{\text{design}}\) cannot be reported yet due to the necessity of test certificates for some of the concrete constituents, which is based on the feedback obtained from the contractor and concrete batching plant operator towards such requirement.

For each of the practice to be measured, quality criteria will be measured against placing, compaction and curing. This paper will not formulate the complete quality measurement as the formulation is rather extensive. However the procedure will be demonstrated in the next section of this paper.

V. DATA COLLECTION

A study is being conducted on the quality of concrete practice involving construction of a 13 storey concrete structures for an office complex in Kuala Lumpur, Malaysia. The study commenced from construction of the pile caps and to date the construction has progressed until level three. Q\(_{\text{design}}\), Q\(_{\text{concrete production}}\) and Q\(_{\text{construction}}\) have been measured throughout the construction works and data have been collected to identify the score for quality of concrete practice for the concrete works. This paper will report on the preliminary findings of the measured quality for Q\(_{\text{design}}\) and Q\(_{\text{construction}}\). Q\(_{\text{concrete production}}\) could not be reported yet due to the necessity of test certificates for some of the concrete constituents, which is based on the feedback obtained from the contractor and concrete batching plant operator towards such requirement.

For each of the practice to be measured, quality criteria are set in the form of a check list. As the works progressed, these criteria will be checked against the actual practice and score given. The maximum score is 5 and the minimum score is 1. For a systematic data collection, the quality measurement is being categorized in terms of the structural components such as slabs, beams, columns and walls. By having such performance measurement categorization, the actual concrete practice data from design through to completion of the concreting works for any particular component can be retrieved easily.

The various attributes which are being measured are as follows:

1) Reinforcement detail: To check whether the details specified by designer are congested for placement of concrete

2) Sizing of structural members: To check whether the member sizes specified by designer is difficult for concrete to be handled or not constructible

3) Spacing of reinforcement: To check whether the spacing of reinforcement is sufficient for concrete to be filled

4) Reinforcement condition: To check whether the reinforcement is clean and free from deleterious material

5) Services: To check whether the designer has specified sufficient drawings for services to avoid hacking of members at later date

6) Truck: To check whether the concrete delivery vehicle is clean and possess the adequate tools for tracking the concrete quality from plant to site

7) Delivery: To check whether the concrete is delivered to site and placed within acceptable time

8) Accessibility: To check whether easy access is provided to the concreting location

9) Handling: To check whether proper handling method is provided from concrete truck to concreting location

10) Concrete placement: To check whether the concrete is placed as required by good concreting practice

11) Temperature: To check whether concrete is being deposited at permissible temperature

12) Tools: To check whether adequate tools are used for compaction works

13) Workers: To check whether adequate workers are provided to do compaction works

14) Compaction method: To check whether the compaction is being done according to good concreting practice

15) Joints: To check whether the construction joints are done properly

16) Curing: To check whether proper curing method is being deployed

17) Curing duration: To check whether sufficient curing period is provided to the structural elements

Attributes 1 to 5 constitutes Q\(_{\text{design}}\), 6 and 7 constitutes part of Q\(_{\text{concrete production}}\) and 8 to 17 constitutes Q\(_{\text{construction}}\).

VI. RESULTS AND ANALYSIS

Results for five structural elements based on the criteria set for the different attributes are shown in Table 1:

From the results the following are computed

<table>
<thead>
<tr>
<th>Results</th>
<th>Q(_{\text{design}})</th>
<th>Q(_{\text{concrete production}})</th>
<th>Q(_{\text{construction}})</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>23/25x100=92</td>
<td>7/10x100=70</td>
<td>36/50x100=72</td>
</tr>
<tr>
<td>2</td>
<td>92</td>
<td>70</td>
<td>72</td>
</tr>
<tr>
<td>3</td>
<td>92</td>
<td>70</td>
<td>80</td>
</tr>
<tr>
<td>4</td>
<td>84</td>
<td>70</td>
<td>62</td>
</tr>
<tr>
<td>5</td>
<td>84</td>
<td>60</td>
<td>58</td>
</tr>
</tbody>
</table>

It should be highlighted that Q\(_{\text{transportation}}\) is introduced at this stage because Q\(_{\text{concrete production}}\) which encompass Q\(_{\text{transportation}}\) is not available at the time of this study. These
results however reflect the quality of overall concrete practice to some extend even though the complete quality concrete practice score could not be computed yet.

TABLE I. RESULTS OF MEASURED QUALITY

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Result 1</th>
<th>Result 2</th>
<th>Result 3</th>
<th>Result 4</th>
<th>Result 5</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pilecap</td>
<td>Pilecap</td>
<td>Basement</td>
<td>Beam</td>
<td>Column</td>
</tr>
<tr>
<td>Reinf Detail</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>Sizing</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Spacing</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Rein Cond</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Services</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Truck</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Delivery</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Accessibility</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>Handling</td>
<td>3</td>
<td>3</td>
<td>5</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Conc Placement</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>Temperature</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Tools</td>
<td>3</td>
<td>5</td>
<td>5</td>
<td>3</td>
<td>5</td>
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<td>Workers</td>
<td>3</td>
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<td>5</td>
<td>5</td>
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<tr>
<td>Compaction</td>
<td>3</td>
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<td>3</td>
<td>2</td>
<td>2</td>
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<tr>
<td>Joints</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Curing</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Duration</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

From the results, the followings are observed:

1) The minimum quality of design is 84% and the maximum is 92%
2) The minimum quality of concrete transportation is 60% and the maximum is 70%
3) The minimum quality of construction is 58% and the maximum is 80%

The results are also plotted in order of the quality attributes explained in the previous section. This order is important because it relates exactly to the sequence of process taking place i.e. from design to construction. The trend line is also obtained from these curves to assess the general trend of quality of the process taking place. To demonstrate the curve for the results obtained, plot for Result 1 and Result 5 is shown in Fig. 2.

Base on the five structural components, the maximum drop in quality of design is 16%. The main reason recorded is unsatisfactory condition of steel reinforcement (Result 1, 2, 3, 4). This indicates the lack of awareness of contractor to the importance of having good condition and clean steel reinforcement so that bonding between steel and concrete will not be affected. The sizing of structural elements (Result 4, 5) is also a factor that reduces the quality which indicates either the architect require the size for a particular reason or the structural engineer is too economical in their design.

The maximum drop in quality of transportation is 40%. The factor responsible for the drop is unsatisfactory condition of the truck mixer in terms of maintenance and proper measures to monitor the delivery of concrete. All results show that the concrete are sent to concreting location within 45 minutes after mixing. This indicates the availability of batching plant nearby to the construction works site.

The maximum drop in quality of construction is 42%. The main reason for the drop is found to be from non conformance to temperature requirement during placement and too short a curing period. This finding is very useful because it reflects the understanding of contractor and the workers towards having good quality concrete. Other factor responsible for the drop in quality of construction is handling of concrete. Almost all the results show that crane and bucket system is used for concrete handling, a system which will promote concrete segregation if not carefully done. Compaction is also found to be the cause for reduction in quality of construction. From the data measured, it is found that the workers do not compact the concrete to normal good practice procedure such as compacting the concrete immediately after placing, vibrate at acceptable rate, compact in layers and when to stop the compaction.

Based on the preliminary results, it can be deduced that design of the structural elements is not a major problem that reduces the quality of concrete. Transportation of concrete from the batching plant to construction site is a problem to the environment and contributes to reduction of concrete.
quality. The quality of construction is a major factor affecting the environment and the quality of concrete. The wide variation in drop of quality (20 to 42%) indicates that the level of awareness in this sector of the construction industry needs to be uplifted.

From Fig.2 it can also be seen that the quality of concrete practice deteriorates as the process move from design to construction.

VII. CONCLUSION

Concrete has been used by mankind as a useful construction material. Due to its variability in characteristics, the quality of the concrete products has been a recurring problem. As the material is extensively being used in the construction industry, associated environmental problems are being aggressively addressed. Actions by legislative means and replacement with alternative materials will not be effective if the concrete practice itself does not have the required quality.

The concrete practice processes in the construction industry has been explained and furthermore a method of performance measurement of concrete practice has been formulated.

Based on the data collection of various concrete practice attributes for a 13 storey office complex in Kuala Lumpur, Malaysia, the actual concrete practice measurements have been presented. From the preliminary data it is concluded that quality of design is within acceptable quality level. The quality of concrete practice is very much affected by the construction works. Thus in order to improve the environmental impact of construction industry, this is one area that needs significant improvement.

REFERENCES