The Effectiveness and Efficiency of Implementing Fast Set Concrete in Reparation and Reinstatement of Concrete Pavements

Teoh Sze Tean1

1ECO2 BUILDER PTE LTD, 12 Woodlands Square #07-75 Singapore 737715
WOODSQUARE TOWER 1
* Corresponding author: teoh@ecotwo.sg

Abstract. The aim of this research is to determine the average compressive strength of fast set concrete with different formulations and their viabilities to be adopted for reparation and reinstatement works in concrete pavements especially when time is critical consideration. Fosroc’s Patchroc Rapid Setting Patch (RSP) cement was used as one of the components of the concrete. Conventionally, the recommended thickness for fast set concrete is only up to 75mm. With the technical supports from Fosroc (UK), we made a breakthrough by manipulating the design mix ratio and allow the fast set concrete remains its optimum performance with thickness up to 400mm. For the testing methodology, ten batches of concrete cube samples were produced, and each batch consists of ten numbers of samples. We are working on different mix design to determine the design with highest strength. All samples are tested in laboratory to ascertain their compressive strengths at 3 hours, 4 hours, 5 hours, 6 hours, 1 day, 3 days, 7 days, 28 days, 60 days and 90 days. Findings and analysis from several successful fast set concrete projects in Singapore Changi Airport were carried out and the data will be presented in this paper as well. Based on the most recent results, we are able to produce fast set concrete that achieve initial compressive strength more than 40MPa at 3 hours and the strength is increasing gradually with time. The projects using fast set concrete in aircraft pavement reparation and reinstatement were effective and efficient with minimum disturbance to the aircraft operation. From these results, we can conclude that fast set concrete could bring remarkable benefits and contributions to reparation and reinstatement works on operational area. This is because fast set concrete able to gain high early strength and the time for closure can be reduced drastically.

Keywords: fast set concrete, effective and efficient, pavement repair, pavement reinstatement

1. Introduction
Structures built by concrete including builds, bridge decks, road pavements, and aircraft pavements will deteriorate over time due to usage, loading and environmental factors. When concrete starts to deteriorate, defects such as cracks, spalling, bond splitting and others will occur and jeopardize the structural integrity of the concrete structures. If these defects are left unattended, severe, and fatal accidents may occur and result in lots of losses including lives. Therefore, concrete reparation is a

Content from this work may be used under the terms of the Creative Commons Attribution 3.0 licence. Any further distribution of this work must maintain attribution to the author(s) and the title of the work, journal citation and DOI.
Published under licence by IOP Publishing Ltd
crucial field in the construction industry in order to extend and preserve the structural life span of the concrete structures.

However, concrete reparation is not a simple task as it seems. In operational area such as aircraft pavements in airport, concrete reparation is subjected to numerous of constraints especially for airport with high intensity of air traffic namely Singapore Changi Airport. The operation of Changi Airport covers over 100 airlines which are flying to 400 cities and 100 countries. There are about 7,400 flights depart or land in Changi Airport. Besides runway, most of the aircraft maneuver areas are constructed in concrete pavements such as taxiway entrances, parking bays etc. Thus, during reparation works are carried out on the concrete pavement, time required for reparation, areas of closure, duration of closure and the disruption to the airport operation shall be kept at the minimum.

Therefore, fast set concrete is being used in concrete reparation works in airport operation areas where time is a critical concern [1,2]. Fast set concrete is a type of concrete which can gain early strength rapidly and achieve adequate amount of strength in shorter period of time as compared to ordinary concrete. On the other hand, the usage of fast set concrete reduces the overall time required for concrete curing. With such advantages of fast set concrete, reparation works on the defective concrete can be completed in a timely manner and minimize the disturbance to airport operations.

The aim of this research is to study the effectiveness and efficiency of implementing fast set concrete in reparation and reinstatement of concrete pavements especially for operational area such as airport. In order to study the effectiveness and efficiency of the fast set concrete, the compressive strength of the fast set concrete in the relation of time shall be determined.

2. Research Methodology
Experimental: 10 batches of concrete samples were produced by using fast set concrete and each batch of concrete consists of 10 concrete cube samples. One of the main components of the fast set concrete used in this research is Fosroc’s Patchroc Rapid Setting Patch (RSP). All of the concrete sample were set to a third party laboratory, Admaterials Technologies Pte Ltd, to determine the compressive strengths of the concrete samples at time interval of 3 hours, 4 hours, 5 hours, 6 hours, 1 day, 3 days, 7 days, 28 days, 60 days and 90 days.

Before the experiment was carried out, a correlational study was conducted with technical supports from Fosroc (UK) to study the mix ratio and design mix of the fast set concrete. Despite the conventional fast set concrete is recommended to be casted not more than 75mm thick, a breakthrough was made by discovering a design which allow the fast set concrete to be casted up to 400mm thick while remain its structural characteristics.

3. Result and Findings
As the results, the fast set concrete is able to achieve high early strength as reflected in the results shown below (figure 1 and table 1). At time interval of 3 hours, the fast set concrete had already gained an average compressive strength of 43.53 MPa and the strength is increasing gradually over time. At 6 hours, it has already achieved compressive strength of 50.49 MPa. At 28 days, the compressive strength has developed to 64.85Mpa and continues to increase to 93.11Mpa and 96.26Mpa at 60 days and 90 days respectively.
Table 1. Average Compressive Strength achieved by Fast Set Concrete Over Time.

| Durations | Batch 1 | Batch 2 | Batch 3 | Batch 4 | Batch 5 | Batch 6 | Batch 7 | Batch 8 | Batch 9 | Batch 10 | Avr. Compressive Strength (MPa) |
|------------|---------|---------|---------|---------|---------|---------|---------|---------|---------|---------|----------------------------------|
| 3 hours    | 38.9    | 36.1    | 43.8    | 54.5    | 42.8    | 46.9    | 45.0    | 40.4    | 48.8    | 38.1    | 43.53                             |
| 4 hours    | 40.8    | 38.0    | 48.5    | 55.1    | 49.0    | 47.0    | 50.5    | 40.2    | 47.2    | 41.6    | 45.79                             |
| 5 hours    | 44.2    | 50.7    | 54.1    | 53.6    | 51.3    | 48.4    | 48.3    | 41.5    | 53.5    | 45.3    | 49.09                             |
| 6 hours    | 41.9    | 47.2    | 54.8    | 54.9    | 55.8    | 46.4    | 48.2    | 49.0    | 59.6    | 47.1    | 50.49                             |
| 1 day      | 52.7    | 55.4    | 57.4    | 61.8    | 56.3    | 50.0    | 60.3    | 55.7    | 63.3    | 53.5    | 56.64                             |
| 3 days     | 57.0    | 58.7    | 62.9    | 66.7    | 58.5    | 56.6    | 59.0    | 57.0    | 70.7    | 53.6    | 60.07                             |
| 7 days     | 62.5    | 70.9    | 67.0    | 69.5    | 61.2    | 65.6    | 61.8    | 59.8    | 72.7    | 57.5    | 64.85                             |
| 28 days    | 77.9    | 82.3    | 95.8    | 80.9    | 91.0    | 89.2    | 92.0    | 80.8    | 94.7    | 84.6    | 86.92                             |
| 60 days    | 83.4    | 85.0    | 98.0    | 95.2    | 95.1    | 97.4    | 95.2    | 90.5    | 101.7   | 89.6    | 93.11                             |
| 90 days    | 90.7    | 90.0    | 99.3    | 101.3   | 98.8    | 100.0   | 96.5    | 93.2    | 102.3   | 90.5    | 96.26                             |

Figure 1. Graph of Compressive Strength of 10 batches of Concrete Sample vs Time.

Based on the results shown above, fast set concrete is able to achieve high early strength with average compressive strength of 43.53 MPa in 3 hours which is as good as ordinary mix of grade 40 concrete which can only reach compressive strength about 40 MPa at 28 days.

Maturity method can be implied to determine the strength of the concrete when the fast set concrete is casted on site and testing equipment is absent [3]. Maturity method is an approach to determine the concrete strength with the relation of temperature and time. The basis of this method uses the fundamental concept of heat releases while the concrete its developing its properties and gaining strength due to chemical reactions between cement, water and other components in the concrete.
Figure 2. Graph of Temperature / Heat Releases from Fast Set Concrete vs Time.

From figure 2 above, it can be observed that the fast set concrete starts to release a significant amount of heat and reach the optimum temperature within the first hour of concrete casting. It is due to the concrete is gaining strength and reactions take place rapidly and allow the concrete to achieve high early strength at the first hour.

If fast set concrete is being implemented as the major concrete repair in airport operational areas, the duration of the working hours and closures can be reduced drastically. Most importantly, the repair area can be opened and resume its operation as soonest at 3 to 6 hours.

4. Conclusion
Repairing defective concrete pavement with fast set concrete is an effective and efficient method. The characteristics and properties of fast set concrete enable it to develop sufficient amount of early strength and allows the defective concrete pavements to be repaired at soonest as several hours. As the result, the disruption to the operational areas is kept as the lowest rate and risks are minimized also. Nevertheless, repairing defective concrete pavement with fast set concrete may be costly and it requires specialized contractors or builder to execute the works. However, by considering the benefits of fast set concrete and the way it can enhance the effectiveness and efficiency in concrete repairing works, fast set concrete is still one of the best choices to be utilized and implemented. Other than airports, fast set concrete can also be used to repair concrete pavements or structures in other operational areas namely expressway, bus bays, bridge decks etc.

5. References
[1] Mays, Ged., Durability of Concrete Structures: Investigation, Repair, Protection, first edition, E&FN Spon, New York, 2002, 288 pp.
[2] Mo Li, Victor C. Li, High-Early-Strength Engineered Cementitious Composites for Fast, Durable Concrete Repair—Material Properties, 2011
[3] National Ready Mixed Concrete Association, Maturity Methods to Estimate Concrete Strength, 2006