

**SULIT**

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First Semester Examination  
Academic Session 2020/2021

February 2021

**EAS662 – Structural Retrofitting Technology**

Duration : 2 hours

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Please check that this examination paper consists of **SEVEN (7)** pages of printed material before you begin the examination.

**Instructions** : This paper contains **FIVE (5)** questions. Answer **FOUR (4)** questions.

Each question **MUST BE** answered on a new page.

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**SULIT**

- (1). (a). Nowadays incidents of fires in buildings are often heard which are increasing day by day and the repair and rehabilitation of fire damaged structures have become areas for study and research. On 4<sup>th</sup> August 2020, a large amount of ammonium nitrate stored in the port of the capital city of Lebanon has triggered explosion which caused damages to a large numbers of building due to fire and flame. The building surrounded the area of explosion consist of reinforced concrete structures and historical buildings as shown in **Figure 1**.

In such case and scenarios, an investigation process must be carried out to assess the behavior of fire damaged building. Explain in details the precise methods for completing a logical examination of flame damaged structures influenced by the explosion and the parameters that are needed to be assessed by using **Non-Destructive Test (NDT)**. The explanation must include the following:

- (i). Detailed investigation process for the structural condition assessment of structures surrounding the explosion.
- (ii). Evaluation methods/tests with their limitation's in quantifying the mechanism and extent of fire damage.

[25 marks]



**Figure 1**

(2). (a). The Penang Port Commission has decided to expand its North Butterworth container terminal to cater for the increasing demand in container space from the escalating number of ships and vessels loading and unloading cargo containers at the port. Hence, a suitable concrete mixture is required for the expansion work of the cargo/container terminal. The consulting engineering firm in charge of the project has imposed stringent requirements on the concrete as part of the performance-based specification for the port expansion's project to ensure that the relevant structures will have adequate durability performance in the aggressive marine exposure. Among the requirements:

- (i). Slump value of at least  $180 \pm 25$  mm at the jobsite to ensure ease of placing and compaction in heavily reinforced structural members.
- (ii). Low heat evolution to compliment temperature control measure undertaken during construction (maximum temperature gradient  $\leq 28^{\circ}\text{C}$ ).

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- (iii). 28-day compressive strength in excess of 80 MPa.
- (iv). Total charge passed based on the Rapid Chloride Permeability Test (RCPT) of not more than 1000 coulombs.
- (v). Absorption value based on the Initial Surface Absorption Test (ISAT) of not more than 0.05 ml/m<sup>2</sup>/s.

As the project is still at its pre-construction stage, various concrete trial mixes have been undertaken by the appointed contractor utilizing mostly ordinary Portland cement based high strength concrete mixtures. The outcomes indicate that the strength and workability requirements could be achieved. Nonetheless, the same concrete mixtures failed to comply with the stringent stipulated durability performance requirements based on the RCPT and the ISAT by significant margin, as well as did not facilitate in lowering heat evolution.

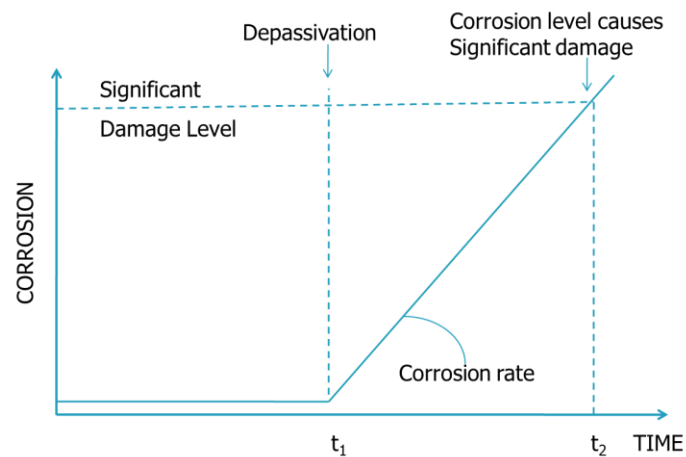
Suggest and justify suitable combination of admixtures that could be used together with ordinary Portland cement and other materials in the concrete mixture to ensure total compliance with the stipulated requirements. The justification should include how the suggested combination of admixtures contributes towards conformance of the concrete to the specified requirements.

[25 marks]

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- (3). (a). Explain the corrosion phenomena of steel in concrete based on the two major causes of depassivation of steel in concrete using the illustration in **Figure 2**.



**Figure 2** : Graphical illustration of corrosion of steel in concrete

[12 marks]

- (b). Several piers of a reinforced concrete marine jetty have been repaired by form and pump method of concrete repair. The repair work performed focuses only on the parts of the piers exposed to tide movement (tidal zone), which exhibited cracking and spalling as a result of corrosion of reinforcement, but not including the splash zone due to budget constraint. Three months after the repair work, sign of corrosion and cracking have been observed on some areas of the piers within the splash zone which are adjacent to the previously repaired areas. Explain the phenomenon and mechanism of the observed corrosion. Suggest suitable measure to reduce the risk or prevent the occurrence of such corrosion phenomenon.

[13 marks]

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- (4). (a). From a limited periodic inspection work performed on a number of piers and cross beams of a highway bridge near Sheffield, England it was reported that chloride content in excess of the threshold limit has penetrated the concrete cover up to a depth of about 40 mm and half-cell potential mapping exhibited some areas with high negative (-ve) potential, indicating high probability of corrosion occurring in the tested structural members. Nonetheless, no signs of severe corrosion in the forms of cracking and spalling of concrete cover were reported during the visual inspection, despite the high chloride content and high -ve potential values of the half-cell. Physical calibration on a few of the suspected areas indicates negligible to minor corrosions (early stage of corrosion) without apparent loss in cross sectional area of steel rebar. Based on the findings of the limited inspection and testing work, the highway authority has decided that appropriate measure should be taken to all of the piers and cross beams of the highway bridge to prevent or arrest further corrosion which would be very costly to rehabilitate once the corrosion of reinforcement reaches advanced stage. With justifications, propose a suitable retrofitting or repair scheme that could be undertaken to cease the corrosion problem so as to extend the service life of the highway bridge. Explain the repair process with the help of suitable sketches.

[15 marks]

- (b). A retrofitting work will be carried out to rehabilitate reinforced concrete columns of a multi-storey car park which have exhibited extensive cracking and spalling due to carbonation induced corrosion. The surrounding temperature is stable throughout the year. To ensure that loads are distributed equally throughout the area of the affected columns, the repair area should carry part of the imposed load. Further, to ensure effective load sharing as well as durable repair work, the selected repair material should possess certain important properties. Identify and explain **FIVE (5)** of those important properties with appropriate justification for each one.

[10 marks]

- (5). (a). Nowadays, with the support of new technology, structures can now be repaired at any location or situation. Your task is to propose a method statement to repair an underwater pier that needs a professional diver to do the job. You can use a suitable sketch to describe your answer.

[15 marks]

- (b). Fibre Reinforced Polymer (FRP) is a versatile material. Many structural issues can be solved just by using this FRP. Discuss **FIVE (5)** characteristics of the Fibre Reinforced Polymer (FRP) which make it a good material for strengthening of structures.

[10 marks]

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