

**University Of Technology**  
**Building and Construction Eng. Dept.**  
**Final Exam**

**Subject :Quality Control**

**Division: Building Eng. & Projects management**

**Examiner : MAAN S. HASSAN (PhD)**

**2012/2013**

**Class: 3<sup>rd</sup>**

**Time : 3 Hours**

**Date : 2016 / 2013**

**[Answer 4 questions only including No. 2] [اجب عن اربعة اسئلة فقط على ان يكون الثاني من ضمنها]**



**Q1:** According to ISO 9001, what are the quality control requirements for the:

- Process control.*
- Purchasing*
- Document and data control.*
- Control of non-conforming product.*
- Design control.*

25%

**Q2:** The following chemical and physical test results have been reported from a construction laboratory for 2 different ordinary Portland cement samples (Type I). Evaluate the results and:

- Calculate the main compounds ( $C_3S$ ,  $C_2S$ ,  $C_3A$ ,  $C_4AF$ )?
- Are the results complying with the ASTM specification C150? & Iraqi specification?

**Chemical analysis**

| Oxide                  | Abbreviation | Cement No. 1 | Cement No. 2 | ASTM specification C150 | Iraqi specification | Notes |
|------------------------|--------------|--------------|--------------|-------------------------|---------------------|-------|
| $SiO_2$ (%)            | S            | 21.1         | 21.1         |                         |                     |       |
| $Al_2O_3$ (%)          | A            | 5.2          | 6.2          |                         |                     |       |
| $Fe_2O_3$ (%)          | F            | 3.9          | 2.9          |                         |                     |       |
| $CaO$ (%)              | C            | 65           | 65           |                         |                     |       |
| $SO_3$ (%)             | S            | 2.0          | 2.0          |                         |                     |       |
| $MgO$ (%)              |              | 1.9          | 2.0          |                         |                     |       |
| $Na_2O$ (%)            |              | 0.2          | 0.19         |                         |                     |       |
| $K_2O$ (%)             |              | 0.4          | 0.4          |                         |                     |       |
| Insoluble residual (%) | I.R          | 0.2          | 0.2          |                         |                     |       |
| Loss on ignition (%)   | L.O.I        | 2.4          | 2.2          |                         |                     |       |

**Physical results**

| Test                              | Cement No. 1 | Cement No. 2 | ASTM specification C150 | Iraqi specification | Notes |
|-----------------------------------|--------------|--------------|-------------------------|---------------------|-------|
| Fineness (Blaine method) $m^2/kg$ | 310          | 280          |                         |                     |       |
| Autoclave expansion (%)           | 0.19         | 0.32         |                         |                     |       |
| Compressive strength $N/mm^2$     |              |              |                         |                     |       |
| 3 days                            | 20           | 17           |                         |                     |       |
| 7 days                            | 27           | 23           |                         |                     |       |
| 28 days                           | 33           | 30           |                         |                     |       |
| Time of setting                   |              |              |                         |                     |       |
| Initial set                       | 1:20 hr      | 1:30 hr      |                         |                     |       |
| Final set                         | 6 hr         | 8 hr         |                         |                     |       |

25%

**Q3:** what are the QC requirements on the design and construction stage of formwork?

25%

**Q4:** The following results are the concrete strength for the previous and current months.

1. Draw Cusum control chart and indicate the change point?
2. Draw Shewhart control chart and calculate the number of results that have exceeded warning level (1/20) and LCL, UCL?

|            | Previous month (N/mm <sup>2</sup> ) |    |    |    |    |    |    |    |    |    | Current month (N/mm <sup>2</sup> ) |    |    |    |    |    |    |    |    |    |
|------------|-------------------------------------|----|----|----|----|----|----|----|----|----|------------------------------------|----|----|----|----|----|----|----|----|----|
| Strength   | 37                                  | 38 | 35 | 38 | 38 | 40 | 36 | 35 | 38 | 37 | 36                                 | 35 | 36 | 37 | 35 | 36 | 34 | 35 | 34 | 33 |
| Sample No. | 1                                   | 2  | 3  | 4  | 5  | 6  | 7  | 8  | 9  | 10 | 1                                  | 2  | 3  | 4  | 5  | 6  | 7  | 8  | 9  | 10 |

25%

**Q5 (A):** what are the QC requirements for transport of fresh concrete?

15%

**Q5 (B):** what are the measures that should be adopted for fresh concrete in cold weather?

10%

**BOGUE EQUATIONS:**

$$\%C_3S = 4.071C - 7.6S - 6.718A - 1.43F - 2.85\hat{S}$$

$$\%C_2S = 2.867S - 0.7544C_3S$$

$$\%C_3A = 2.650A - 1.692F$$

$$\%C_4AF = 3.043F$$



السمنت البورتلاندي  
Portland Cement  
(م.ق. ع ٥ لسنة ١٩٨٤)

أولاً: المتطلبات الفيزيائية  
بموجب جدول ( ١ )

جدول ( ١ ) : المتطلبات الفيزيائية

| ت | الفحص  | نوع السمنت         |                              |                     |                    |                    |
|---|--|--------------------|------------------------------|---------------------|--------------------|--------------------|
|   |  | اعتيادي            | معتدل<br>المقاومة<br>للالملح | سريع<br>التصلد      | واطن<br>الحرارة    | مقاوم<br>ابيض      |
| ١ | النعومة بطريقة بلين لا تقل عن (٢٠كغم)<br>Fineness  | ٢٣٠                | ٢٥٠                          | ٣٢٠                 | ٣٢٠                | ٢٣٠                |
| ٢ | وقت التماسك<br>* الابتدائي لا يقل عن (دقيقة)<br>* النهائي لا يزيد على (ساعة)   | ٤٥<br>١٠           | ٤٥<br>١٠                     | ٤٥<br>١٠            | ٤٥<br>١٠           | ٤٥<br>١٠           |
| ٣ | السلامة:<br>Autoclave expansion<br>الشبث لا يزيد عن (%)  | ٠,٨                | ٠,٨                          | ٠,٨                 | ٠,٨                | ٠,٨                |
| ٤ | تحمل الضغط * لا يقل عن ميكانيوتن/م <sup>٢</sup><br>* بعمر يوم واحد<br>* بعمر ثلاثة أيام<br>* بعمر سبعة أيام<br>* بعمر ٢٨ يوم | -<br>١٥<br>٢٣<br>- | -<br>١٥<br>٢٣<br>-           | ١١<br>٢١<br>٢٨<br>- | -<br>١٠<br>-<br>٢٨ | -<br>١٥<br>٢٣<br>- |
| ٥ | تحمل الشد<br>(اختياري) (ميكانيوتن/م <sup>٢</sup> ) بعمر يوم واحد   | -                  | -                            | ٢,١                 | -                  | -                  |
| ٦ | درجة البياض %  | -                  | -                            | -                   | -                  | ٧٨                 |

\* يجب أن تكون قوة تحمل الانضغاط عند أي عمر لاحق أعلى من قوة التحمل المستحصلة  
عند الفحص بعمر أقل



السمنت البورتلاندي  
Portland Cement  
(م.ق. ع ٥ لسنة ١٩٨٤)

ثانياً : المتطلبات الكيميائية  
بموجب الجدول ( ٢ )

جدول ( ٢ ) : المتطلبات الكيميائية

| ت  | نوع السمنت   | اعتيادي   | معدل      | سريع<br>التصلد | واطن<br>الحرارة | مقاوم     | ابيض      |
|----|--|-----------|-----------|----------------|-----------------|-----------|-----------|
| ١  | SiO <sub>2</sub> لا يقل عن (%)   | -         | ٢١        | -              | -               | -         | -         |
| ٢  | Al <sub>2</sub> O <sub>3</sub> لا يقل عن (%)   | -         | ٦         | -              | -               | -         | -         |
| ٣  | Fe <sub>2</sub> O <sub>3</sub> لا يقل عن (%)   | -         | ٦         | -              | ٦,٥             | -         | -         |
| ٤  | عامل الإشباع الجيري  | ١,٠٢-٠,٦٦ | ١,٠٢-٠,٦٦ | ١,٠٢-٠,٦٦      | ٠,٨٨-٠,٦٦       | ١,٠٢-٠,٦٦ | ١,٠٢-٠,٦٦ |
| ٥  | MgO لا يزيد على (%)  | ٥         | ٥         | ٥              | ٥               | ٥         | ٥         |
| ٦  | محتوى SO <sub>3</sub> لا يزيد على عندما<br>تكون نسبة C <sub>3</sub> A<br>- أقل من (٥%)<br>- أكثر من (٥%) | ٢,٥       | ٢,٥       | ٣              | ٢,٥             | ٢,٥       | ٢,٥       |
| ٧  | الفقدان عند الحرق لا يزيد على %  | ٤         | ٤         | ٤              | ٤               | ٤         | ٤         |
| ٨  | المواد غير القابلة لذوبان لا تزيد<br>على (%)   | ١,٥       | ١,٥       | ١,٥            | ١,٥             | ١,٥       | ١,٥       |
| ٩  | C <sub>3</sub> S لا يزيد على (%)   | -         | -         | -              | ٣٥              | -         | -         |
| ١٠ | C <sub>2</sub> S لا يزيد على (%)   | -         | -         | -              | ٤٠              | -         | -         |
| ١١ | C <sub>3</sub> A لا يزيد على (%)   | -         | ٨         | ١٥             | ٧               | ٣,٥       | -         |
| ١٢ | نسبة Fe <sub>2</sub> O <sub>3</sub> /Al <sub>2</sub> O <sub>3</sub> لا تقل عن                            | -         | -         | -              | -               | -         | ٨         |

الرفض : يمكن رفض العبوات التي تختلف وزنها بنسبة تزيد على ٣٪ من الوزن المؤشر عليها  
وفي حالة كون معدل وزن (٥٠) عبوة منتقاة بصورة عشوائية من إرسالية أقل من الوزن  
المؤشر على العبوات فيمكن رفض الإرسالية .

TABLE 1 Standard Composition Requirements

| Cement Type <sup>a</sup>   | Applicable Test Method | I and IA | I and IA            | II and IIIA | IV              | V               |
|--|------------------------|----------|---------------------|-------------|-----------------|-----------------|
| Silicon dioxide (SiO <sub>2</sub> ), min. %  | C 114                  | ...      | 20.0 <sup>b,c</sup> | ...         | ...             | ...             |
| Aluminum oxide (Al <sub>2</sub> O <sub>3</sub> ), max. %   | C 114                  | ...      | 6.0                 | ...         | ...             | ...             |
| Ferric oxide (Fe <sub>2</sub> O <sub>3</sub> ), max. %   | C 114                  | ...      | 6.0 <sup>d</sup>    | ...         | 6.5             | ...             |
| Magnesium oxide (MgO), max. %  | C 114                  | 6.0      | 6.0                 | 6.0         | 6.0             | 6.0             |
| Sulfur trioxide (SO <sub>3</sub> ), max. %   | C 114                  | ...      | ...                 | ...         | ...             | ...             |
| When (C <sub>3</sub> A) <sup>e</sup> is 8 % or less  | ...                    | 3.0      | 3.0                 | 3.5         | 2.3             | 2.3             |
| When (C <sub>3</sub> A) <sup>e</sup> is more than 8 %  | ...                    | 3.5      | ...                 | 4.5         | ...             | ...             |
| Loss on ignition, max. %   | C 114                  | 3.0      | 3.0                 | 3.0         | 2.5             | 3.0             |
| Insoluble residue, max. %  | C 114                  | 0.75     | 0.75                | 0.75        | 0.75            | 0.75            |
| Tricalcium silicate (C <sub>3</sub> S) <sup>f</sup> , max. %   | See Annex              | ...      | ...                 | ...         | 35 <sup>g</sup> | ...             |
| Dicalcium silicate (C <sub>2</sub> S) <sup>f</sup> , min. %  | See Annex              | ...      | ...                 | ...         | 40 <sup>g</sup> | ...             |
| Tricalcium aluminate (C <sub>3</sub> A) <sup>f</sup> , max. %  | See Annex              | ...      | 2                   | 15          | 7 <sup>g</sup>  | 5 <sup>c</sup>  |
| Tetracalcium aluminoferrite plus twice the tricalcium aluminate (C <sub>4</sub> AF + 2(C <sub>3</sub> A)), or solid solution (C <sub>4</sub> AF + C <sub>2</sub> F), as applicable, max. % | See Annex              | ...      | ...                 | ...         | ...             | 25 <sup>c</sup> |

<sup>a</sup> See Note 2.<sup>b</sup> Does not apply when the heat of hydration limit in Table 4 is specified.<sup>c</sup> Does not apply when the sulfate resistance limit in Table 4 is specified.<sup>d</sup> There are cases where optimum SO<sub>3</sub> (using Test Method C 563) for a particular cement is close to or in excess of the limit in this specification. In such cases where properties of a cement can be improved by exceeding the SO<sub>3</sub> limits stated in this table, it is permissible to exceed the values in the table, provided it has been demonstrated by Test Method C 1038 that the cement with the increased SO<sub>3</sub> will not develop expansion in water exceeding 0.020 % at 14 days. When the manufacturer supplies cement under this provision, he shall, upon request, supply supporting data to the purchaser.<sup>e</sup> See Annex for calculation.<sup>f</sup> Not applicable.

TABLE 3 Standard Physical Requirements

| Cement Type <sup>a</sup>   | Applicable Test Method | I              | IA             | II                                       | IIA                                     | III            | IIIA           | IV            | V              |
|--|------------------------|----------------|----------------|--|---|----------------|----------------|---------------|----------------|
| Air content of mortar, <sup>b</sup> volume %:  | C 185                  |                |                |  |   |                |                |               |                |
| max.   |                        | 12             | 22             | 12                                       | 22                                      | 12             | 22             | 12            | 12             |
| min.   |                        | ...            | 16             | ...                                      | 16                                      | ...            | 16             | ...           | ...            |
| Fineness, <sup>c</sup> specific surface, m <sup>2</sup> /kg (alternative methods):       |                        |                |                |  |   |                |                |               |                |
| Turbidimeter test, min.  | C 115                  | 150            | 150            | 150                                      | 150                                     | ...            | ...            | 150           | 150            |
| Air permeability test, min.  | C 204                  | 280            | 280            | 280                                      | 280                                     | ...            | ...            | 280           | 280            |
| Autoclave expansion, max. %  | C 151                  | 0.80           | 0.80           | 0.80                                     | 0.80                                    | 0.80           | 0.80           | 0.80          | 0.80           |
| Strength, not less than the values shown for the ages indicated as follows: <sup>d</sup> |                        |                |                |  |   |                |                |               |                |
| Compressive strength, MPa (psi):   | C 109/<br>C 109M       |                |                |  |   |                |                |               |                |
| 1 day  |                        | ...            | ...            | ...                                      | ...                                     | 12.0<br>(1740) | 10.0<br>(1450) | ...           | ...            |
| 3 days   |                        | 12.0<br>(1740) | 10.0<br>(1450) | 10.0<br>(1450)                           | 8.0<br>(1160)                           | 24.0<br>(3480) | 19.0<br>(2760) | ...           | 8.0<br>(1160)  |
| 7 days   |                        | 19.0<br>(2760) | 16.0<br>(2320) | 17.0<br>(2470)                           | 14.0<br>(2030)                          | ...            | ...            | 7.0<br>(1020) | 15.0<br>(2180) |
| 28 days  |                        | ...            | ...            | 12.0 <sup>e</sup><br>(1740) <sup>e</sup> | 9.0 <sup>e</sup><br>(1310) <sup>e</sup> | ...            | ...            | ...           | ...            |
| Time of setting (alternative methods): <sup>f</sup>                                      |                        |                |                |  |   |                |                |               |                |
| Gilmore test:  | C 266                  |                |                |  |   |                |                |               |                |
| Initial set, min. not less than  |                        | 60             | 60             | 60                                       | 60                                      | 60             | 60             | 60            | 60             |
| Final set, min. not more than  |                        | 600            | 600            | 600                                      | 600                                     | 600            | 600            | 600           | 600            |
| Vicat test: <sup>g</sup>   | C 191                  |                |                |  |   |                |                |               |                |
| Time of setting, min. not less than  |                        | 45             | 45             | 45                                       | 45                                      | 45             | 45             | 45            | 45             |
| Time of setting, min. not more than  |                        | 375            | 375            | 375                                      | 375                                     | 375            | 375            | 375           | 375            |

<sup>a</sup> See Note 2.<sup>b</sup> Compliance with the requirements of this specification does not necessarily ensure that the desired air content will be obtained in concrete.<sup>c</sup> The testing laboratory shall select the fineness method to be used. However, when the sample fails to meet the requirements of the air-permeability test, the turbidimeter test shall be used, and the requirements in this table for the turbidimeter method shall govern.<sup>d</sup> The strength at any specified test age shall be not less than that obtained at any previous specified test age.<sup>e</sup> When the optional heat of hydration or the chemical limit on the sum of the tricalcium silicate and tricalcium aluminate is specified.<sup>f</sup> The time-of-setting test required shall be specified by the purchaser. In case he does not so specify, the requirements of the Vicat test only shall govern.<sup>g</sup> The time of setting is that described as initial setting time in Test Method C 191.

Q1

ملف اسئلة السيطرة لتوكيد  
الدور الاول 2013  
فرع البناء وإدارة المشاريع

### ✓ 3.5 Document and data control

The supplier shall establish and maintain documented procedures to control all documents and data that relate to the requirements of this International Standard including, to the extent applicable, documents of external origin such as standards and customer drawings.

*NOTE: Documents and data can be in the form of any type of media, such as hard copy or electronic media.*

### ✓ 3.6 Purchasing

The supplier shall establish and maintain documented procedures to ensure that purchased product conforms to specified requirements.

### ✓ 3.7 Process control

The supplier shall identify and plan the production, installation and servicing processes which directly affect quality and shall ensure that these processes are carried out under controlled conditions.

Controlled conditions shall include the following:

- a) Documented procedures defining the manner of production, installation and servicing, where the absence of such procedures could adversely affect quality;

- b) Use of suitable production, installation and servicing equipment, and a suitable working environment;
- c) Compliance with reference standards/codes, quality plans and/or documented procedures;
- d) Monitoring and control of suitable process parameters and product characteristics;
- e) The approval of processes and equipment, as appropriate;
- f) Criteria for workmanship, which shall be stipulated in the clearest practical manner (e.g. written standards, representative samples or illustrations);
- g) Suitable maintenance of equipment to ensure continuing process capability.

### **3.8 Inspection and testing**

The supplier shall establish and maintain documented procedures for inspection and testing activities in order to verify that the specified requirements for the product are met. The required inspection and testing, and the records to be established, shall be detailed in the quality plan or documented procedures.

### **3.9 Control of nonconforming product**

The supplier shall establish and maintain documented procedures to ensure that product that does not conform to specified requirements is prevented from unintended use or installation. This control shall provide for identification, documentation, evaluation, segregation (when practical), disposition of nonconforming product, and for notification to the functions concerned.

### **3.10 Handling, storage, packaging, preservation and delivery**

The supplier shall establish and maintain documented procedures for handling, storage, packaging, preservation and delivery of product.



Q2

جواب السؤال 2 :-

$$\begin{aligned} \%C_3S &= 4.071 * 65 - 7.6 * 21.1 - 6.718 * 5.1 \\ &\quad - 1.43 * 3.9 - 2.85 * 2.0 \\ &= 264.615 - 160.36 - 34.933 - 5.577 - 5.7 \\ &= 58.045 \end{aligned}$$

$$\begin{aligned} \%C_2S &= 2.867 * 21.1 - 0.7544 * 58.045 \\ &= 60.493 - 43.78 \\ &= 16.70 \end{aligned}$$

$$\begin{aligned} \%C_3A &= 2.65 * 5.2 - 1.692 * 3.9 \\ &= 13.78 - 6.5988 \\ &= 7.1812 \end{aligned}$$

$$\%C_4AF = 3.043 * 3.9 = 11.8677$$

for cement No. 2 :-

$$\begin{aligned} C_3S &= 264.615 - 160.36 - 41.65 - 4.147 - 5.7 \\ \%C_3S &= 52.756 \end{aligned}$$

$$\%C_2S = 60.493 - 39.779 = 20.693$$

$$\%C_3A = 16.43 - 4.906 = 11.5232$$

$$\%C_4AF = 5.8247$$

| oxide                  | Comm | 1    | 2    | Inaqi         | CIS 0                        |
|------------------------|------|------|------|---------------|------------------------------|
| ✓ $SO_3\%$             | 5    | 2.0  | 2.0  | $\leq 2.8$    | $\leq 3.0$ ①<br>$\leq 3.5$ ② |
| ✓ $MgO\%$              |      | 1.9  | 2.0  | $\leq 5.0\%$  | $\leq 6.0\%$                 |
| ✓ I.R. %               |      | 0.2  | 0.2  | $\leq 1.5$    | $\leq 0.75$                  |
| ✓ L.O.I                |      | 2.4  | 2.2  | $\leq 4.0$    | $\leq 3.0$                   |
| ✓ Pineness<br>$m^2/Kg$ |      | 310  | 280  | $\geq 230$    | $\geq 280$                   |
| ✓ $exp\%$              |      | 0.18 | 0.32 | $\leq 0.8\%$  | $\leq 0.8\%$                 |
| ✓ Comp. 3 days         |      | 20   | 14   | $\geq 15$     | $\geq 12$                    |
| 7 days                 |      | 28   | 23   | $\geq 23$     | $\geq 19.0$                  |
| 28 days                |      | 33   | 30   | —             | —                            |
| Time of setting        |      |      |      |               |                              |
| initial set            |      | 1:20 | 1:30 | $\geq 45$ min | $\geq 45$ min                |
| Final set              |      | 6    | 8    | $\leq 10$ hr  | $\leq 6.25$ hr               |

|         | ①     | ②     |
|---------|-------|-------|
| $C_2S$  | 58    | 52.7  |
| $C_3S$  | 16.73 | 20.72 |
| $C_2A$  | 7.18  | 11.55 |
| $C_4AF$ | 11.65 | 8.82  |
|         | 56    |       |

Q3:

## QC requirements for Formwork

**BS 5328-3:1990**

### 1- Design and construction

The design and construction of formwork should take account of safety and of the surface finish required. The formwork should be sufficiently rigid and tight to prevent loss of grout or mortar from the fresh concrete. Consideration should be given to the need to nominate a falsework coordinator whose duties would be similar to those outlined in BS 5975.

Formwork and its supports should maintain their correct position and be to correct shape and profile so the final concrete structure is within the limits of the dimensional tolerances specified. They should be designed to withstand the worst combination of self-weight, reinforcement weight, wet concrete weight, concrete pressure, construction and wind loads, together with all incidental dynamic effects caused by placing, vibrating and compacting the concrete. Guidance on these loadings is given in The Concrete Society Manual *Formwork — Guide to good practice*<sup>(9)</sup>, and in CIRIA Report 108, *Concrete Pressure on Formwork*,<sup>(10)</sup> and in BS 5975.

Before permanent formwork is used in the structure, its durability and compatibility with adjoining concrete should be established. It should be properly anchored to the concrete.

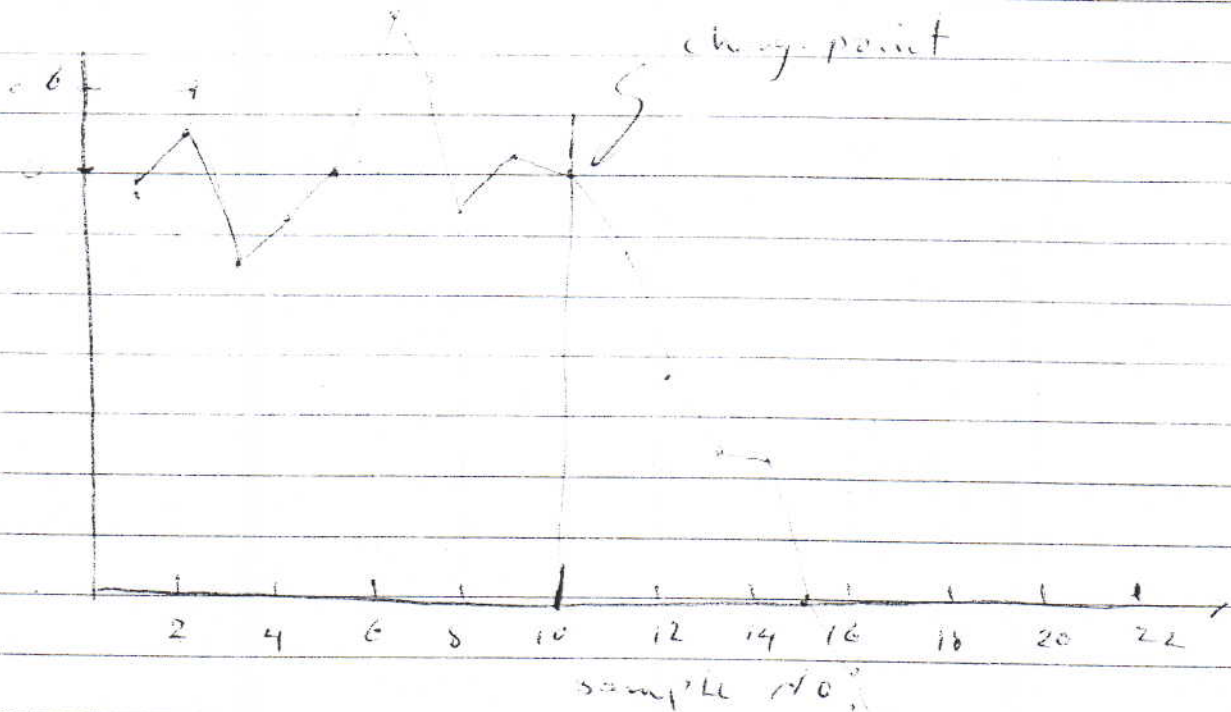
Formwork spacers left in-situ should not impair the desired appearance or durability of the structure, e.g. by causing spalling, rust staining or allowing the passage of moisture. Recommendations for space

Q4:

$$\bar{X} = 37.2$$

$$D = 1.549$$

| $X_i$ | $X_i - \bar{X}$ | $(X_i - \bar{X})^2$ | Cusum | $X_i$ | $X_i - \bar{X}$ | Cusum |
|-------|-----------------|---------------------|-------|-------|-----------------|-------|
| 37    | -0.2            | .04                 | -0.2  | 38    | -1.2            | -1.2  |
| 38    | +0.8            | .64                 | +0.6  | 38    | -2.2            | -3.4  |
| 35    | -2.2            | 4.84                | -1.0  | 38    | -1.2            | -4.6  |
| 38    | +0.8            | .64                 | -0.2  | 34    | -3.2            | -7.8  |
| 38    | +0.8            | .64                 | 0     | 35    | -2.2            | -10.0 |
| 40    | +2.8            | 7.84                | +2.8  | 36    | -1.2            | -11.2 |
| 36    | -1.2            | 1.44                | +1.6  | 31    | -6.2            | -17.4 |
| 35    | -2.2            | 4.84                | -0.6  | 35    | -2.2            | -19.6 |
| 36    | +0.8            | .64                 | +0.2  | 34    | -3.2            | -22.8 |
| 37    | -0.2            | .04                 | 0     | 33    | -4.2            | -27.0 |
|       |                 | 21.6                |       |       |                 |       |







Q5 (B):

## **Quality control requirements for concreting in cold weather**

In cold weather, consideration should be given to the following:

- a) prevention of freezing of the immature concrete;
- b) extended stiffening times which may lead to increased formwork pressures and delays in finishing;
- c) low rate of concrete strength development which may lead to delays in subsequent construction operation such as striking formwork.

To provide confidence that the concrete can resist permanent damage from freezing the temperature of the concrete should, at no point, fall below  $5^{\circ}\text{C}$  until the concrete in the structural element reaches a strength of  $5 \text{ N/mm}^2$  nor should water curing be applied in conditions where freezing of the concrete is anticipated. This should apply regardless of the air temperature at the point of placing. The  $5 \text{ N/mm}^2$  strength requirement may be assessed by tests on cubes cured, as far as possible, under the same conditions as the concrete in the element (see 6.1).

### **Measures which can be adopted for fresh concrete:**

- a) increase the specified minimum temperature of the fresh concrete
- b) incorporation of an accelerating admixture
- c) use of cement that hardens more rapidly;
- d) increase in cement content to raise the heat of hydration

Q5 (A):

## **QC requirements for transport of concrete**

**BS 5328-3:1990**

### **General:**

Concrete shall be transported from the mixer to the point of placing as rapidly as practicable by methods that will maintain the required workability and will prevent segregation, loss of any constituents or ingress of foreign matter or water. The concrete shall be deposited as close as practicable to its final position to avoid rehandling or moving the concrete horizontally by vibration.

### **1- Time of transport:**

Concrete shall be discharged from the delivery vehicle within 2 h after the time of loading, when concrete is transported in truck mixers or agitators, or within 1 h after the time of loading when non-agitating equipment is used unless a shorter time is specified or a longer time permitted by the purchaser. The time of loading shall start from the first contact between cement and aggregates or, when these are surface dry, between cement and added water.

### **2- Quantity of concrete**

The basis of supply shall be by the cubic metre of fresh, fully compacted concrete. The volume of a given batch of concrete shall be calculated from the total mass of the batch divided by the mass per cubic metre.

### **3- Transport of concrete**

Concrete shall be transported in a truck mixer unless the purchaser agrees to the use of non-agitating vehicles. When non-agitating vehicles are used, the mixed concrete shall be protected from gain or loss of water.

### **4- Additional water**

No water, other than any amount required to produce the specified workability, shall be added to the truck mixer drum before discharge unless specifically required and signed for by the purchaser. The water added shall be recorded on the delivery ticket.

## 5- Delivery ticket

Before discharging the concrete at the point of delivery, the supplier shall provide the purchaser with a delivery ticket for each batch of concrete on which is printed, stamped or written the following minimum information:

- a) the name or number of the ready-mixed concrete depot;
- b) the serial number of the ticket;
- c) the date;
- d) the truck number;
- e) the name of the purchaser;
- f) the name and location of the site;
- g) the grade or mix description of the concrete;
- h) the specified workability;
- i) the minimum cement content, if specified;
- j) the type and, if specified, the standard strength class or sub-class of the cement or combination;

- k) the limiting proportions of ggbs or pfa, if specified;
- l) the maximum free water/cement ratio, if specified;
- m) the nominal maximum size of aggregate;
- n) the type or name of admixture, if included;
- o) the quantity of concrete in cubic metres;
- p) the time of loading.

The following information shall be added to the delivery ticket on site:

- q) the time of completion of discharge;
- r) the water added to meet the specified workability;
- s) the extra water added at the request of the purchaser of the concrete, or his representative, and his signature.

NOTE Space should be provided for any additional items.