2013-2012

إصلاحات وتدعيم

Revision

Repair and strengthening

Of R.C. Structure

2012-2013

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Revision

Repair and strengthening

Of R.C. Structure

2012-2013

AIN SHAMS UNIVERSITY
FACULTY OF ENGINEERING
STRUCTURAL ENGINEERING DEPARTMENT
4th Year Structural Engineering

1st Semester, 2010-2011 Course Code: *CES 441* *Time : 3.00 Hrs*

Repair and Strengthening of Structures

The Exam Consists of *Four* Questions in *Two* Pages *Total Marks: 70 Marks* 1/

Question (1): (25%)

a- What are the differences between **repair** and **strengthening** of concrete structures. State briefly with clear sketches the different strengthening methods for concrete structures.

b- What are the objectives of the evaluation of concrete structures. Describe using clear sketches **three** different methods used for in situ evaluation of concrete structures.

c- Define the term "**compatibility**".

d- Discuss the compatibility of the following repair mortars with base concrete?. Which one can be chosen as a suitable repair material for an industrial building? Give your reasons.

Mechanical or Physical Property	Base concrete	Cementitious Mortar	Polymer modified Mortar	Resinous Mortar
Modulus of Elasticity (G.Pa)	20	25	20	15
Coefficient of Thermal Expansion ($C^{-1} \times 10^{-6}$)	11	10	13	28
Maximum Service Temperature (°C)	200	> 300	200	60
Drying shrinkage (micro-strain)	-----	1500	600	150

Question (2): (25%)

a- Differentiate between each of the following techniques used for base concrete surface preparation:

Push hammers – Water jetting – Sand blasting.

b- *"During the evaluation of a reinforced concrete structure it was concluded that some reinforced concrete columns in the basement floor need strengthening."*

state and explain briefly possible methods can be used for the strengthening of these elements (columns).

c- Outline with clear sketches test set-up for each of **slant shear** and **pull-off** tests of bond between repair materials and base concrete.

d- **Tension core pull-off** test was carried out to estimate the bond strength between repair mortar and base concrete, four steel targets of diameter 50 mm were glued to repair surface using a suitable adhesive material. Test results were as follow:

Test No.	Failure load (kN)	Mode of failure
1	7.0	Base failure
2	6.3	Interface failure
3	7.4	Base failure
4	5.5	Repair failure

i) Estimate each of tensile strength of base concrete and the average bond strength between repair mortar and substrate concrete.

ii) Using neat sketches, show the mode of failure for each test.

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Repair and Strengthening of Structures

The Exam Consists of *Four* Questions in *Two* Pages | *Total Marks: 70 Marks* | 2

Question (3): (25%)

1. State down the two types of injection points and the applicability of each type.
2. Compare between each of the following:
   a. Injection and grouting repair techniques.
   b. Concrete replacement and jacketting techniques.
   c. Wet process and dry process in the shotcrete technique.
   d. Configuration of FRP strips for flexural or confinement reinforcing in RC columns.
3. In a tabulated form, illustrate the major drawbacks of stitching repair technique and the corresponding precautions to overcome them.
4. What are the problems associated with the technique of bonded steel plates used for repairing RC beams? On sketches, show how these problems may be solved

Question (4): (25%)

1. Using neat sketches only, explain the following:
   a. Deep active crack in RC slab on grade repaired with and without bond breaker
   b. Arrangement of injection nipples along a vertical crack showing the direction of injection
   c. Different schemes of strengthening isolated RC footing using the jacketing technique
   d. Method of compaction followed in the drypack method
2. Choose the most suitable repair/strengthening technique for each of the following defects in concrete elements:
   a. Deep inter-connected cracks in RC beam
   b. Easy access of corrosive materials
   c. Repair of deep inter-connected voids in RC abutments under water level
   d. Doubling the load carrying capacity of RC columns
   e. Thorough holes in RC walls
   f. Bending cracks in an isolated RC footing
3. Mention the possible alternatives used for each of the following processes in concrete replacement repair technique:
   a. Removal of surface deteriorated concrete
   b. Cleaning of rusted reinforcing bars
   c. Enhancing the bond between old and new concrete

Best Wishes

Ain Shams University
Faculty of Engineering

Repair and Strengthening of Structures

4th Year - Structural Engineering Department

January, 2010
Time Allowed : 3 hours

Atempet all Questions (The Exam. Consists of 4 Questions)

Question (1):

1. What are the differences between rehabilitation and strengthening of concrete structures. Using neat sketches only, discuss the different strengthening methods for reinforced concrete columns.
2. *"In the majority of concrete structures, cracks do not result in structural failure, but they can result in definite loss of performance of structures".*

   Discuss this statement. Using clear skeches, show the crack pattern due to each of the following:

   Over loading for R.C beams – Settlement of plastic concrete in forms – Alkali Silica Reaction.
3. What are the objectives of the evaluation of concrete structures. Discuss each of the following for loading test carried out to evaluate a reinforced concrete flat slab with span 7m in long direction and 5m in short direction given that:

   slab thickness = 25 cm, floor cover load =150 kg/m^2, live load = 500 kg/m^2.

   a. Test load
   b. Test procedure
   c. Measurements
   d. Results obtained & final conclusion
4. Define the term "compatibility".Discuss the compatibility of the following repair materials with base concrete?. Which one can be chosen as a suitable repair material for the repair of concrete floors of an industrial meat plant. Give your reasons.

Mechanical or Physical Property	Base concrete	Cementitious Material	Polymer modified Material	Resinous Material
Modulus of Elasticity (G.Pa)	20	25	20	15
Coefficient of Thermal Expansion ($C^{-1} \times 10^{-6}$)	11	10	13	28
Maximum Service Temperature (^oC)	200	>300	200	60
Drying shrinkage (micro-strain)	-----	1500	600	150

Question (2):

1. Torsion pull-off test was carried out to estimate the shear bond strength between a polymer modified repair mortar and base concrete. Four steel targets of diameter 50 mm were glued to repair mortar surface using a suitable adhesive material. Test results were as follow:

Test No.	Torsional moment at failure (N.mm)	Mode of failure
1	260	Substrate failure
2	230	Interface failure
3	280	Substrate failure
4	240	Interface failure

   a. Estimate each of the torsional shear strength of base concrete and the average shear bond strength between repair mortar and base concrete.
   b. Using neat sketches, show the mode of failure for each test. Give your comments.

Ain Shams University
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4th Year - Structural Engineering Department

Repair and Strengthening of Structures

January, 2010
Time Allowed : 3 hours

2. What are the differences between direct loading bond tests and patch tests for repair works. Discuss test method carried out to estimate the bond strength between carbon fiber reinforced polymers (CFRP) and substrate concrete.

3. Explain the main factors affect the bond strength between repair materials and substrate concrete. Differentiate between each of the following techniques for base concrete surface preparation:

Push hammers – Water jetting – Sand blasting

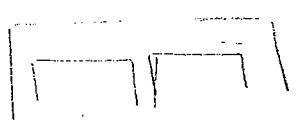
Question (3):

1. Mention the different methods to repair concrete cracks of both active and dormant types. Explain the suitability of each method
2. In case of using internal injection nipples, what are the requirements for the nipple configuration and for the fixing procedure?
3. Note down the advantages of vacum polymer impregnation method compared with traditional pressure injection method to seal very narrow cracks in RC elements
4. Mention the different materials and tools necessary for concrete replacement technique
5. Explain with sketches the possible methods to apply the repair material to existing old concrete in the concrete replacement technique

Question (4):

1. Using neat sketches only, explain the following:
   a. Different geometries of RC jackets for concrete beams
   b. The technique of form and cast in the concrete replacement repair method
   c. Method of compaction followed in the drypack method
   d. Mechanizm of air removal during epoxy injection technique
2. Choose the most suitable repair/strengthening technique for each of the following defects in concrete elements:
   a. A single narrow crack in RC beam.
   b. A straight, deep, wide crack in RC wall.
   c. Map cracks in RC slab.
   d. Surface inter-connected voids in RC column.
   e. Bending cracks in an isolated RC footing.
   f. Splitting crack in RC column.
3. What are the problems associated with the technique of bonded steel plates used for repairing RC beams? On sketches, show how these problems may be solved
4. Explaining the technique on sketches, what are the items to be checked while applying the span shortening technique for strengthening flexural members? Also, how can we take advantage of the moving prob which may be used in this technique? What are the possible alternatives for the intermediate support?

Good Luck



Ain Shams University
Faculty of Engineering
4th Year - Structural Engineering
Department

Repair and Strengthening of Structures

Jan 2009
Time Allowed : 3 hours

Atempet all Questions (The Exam. Consists of 4 Questions)

Question (1):

1) What is the difference between maintenance and protection of concrete structures. Using neat sketches only, discuss the different strengthening methods for concrete structures using additional bonded materials.

2) What are the objectives of the evaluation of concrete structures. Discuss each of the following for the loading test carried out for a reinforced concrete cantiliver slab of free length = 2.0 m, thickness 20 cm, floor cover 150 = kg/cm^2, live load = 300 kg/cm^2 :

a) Test load
b) Test procedure
c) Measurements
d) Results obtained & final conclusion

3) Discuss the effect of each of the following properties on the compatibility of new concrete to an old base concrete:

a) Early drying shrinkage and creep.
b) Modulus of elasticity.
c) Thermal expansion.
d) Poisson's ratio

Question (2):

1) Rewrite each of the following statements and Put sign (√) or (X) beside each of them. If the statement is wrong; put it in the right form:

a) In the majority of concrete structures; cracks result in structural failure.
b) Repair can be defined as to replace or correct deteriorated, damaged, or faulty materials, components, or elements of a structure.
c) Increasing the cross-section of concrete column is more significant strengthening method than increasing the cross section of concrete beam.
d) Placing additional reinforcement in the tension zone of a reinforced concrete beam (protected by an additional concrete cover by shotcrete) is a very effective strengthening method.
e) In the case of structural repair, loaded in compression, the repair material must possess very high creep potential.
f) When selecting a non-structural repair material, designers should ensure that repair material has a higher value of modulus of elasticity than base concrete.
g) Cementitious based materials has similar coefficient of thermal expansion.
h) Creep of repair material increase stresses due to shrinkage at the interface between it and base concrete.

2) Slant shear test was carried out to estimate the shear bond strength between new concrete and old base concrete. Four composite specimens of total dimensions 100 × 100 × 400 mm were cast and tested in compression. The angle of inclination of the interface to the horizontal surface was 60 ° with respect to the horizontal surface. Test results were as follow:

Test No.	Failure load (kN)	Mode of failure
1	180	Splitting
2	150	Sliding
3	160	Splitting
4	145	Sliding

a) Calculate the value of the average shear bond strength.
b) Using neat sketches, show the different obtained modes of failure.

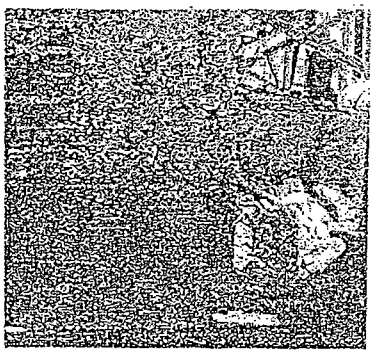
3) Using neat sketches, discuss some applications for each of the following materials used in repair and strengthening works:
   a) Carbon Fiber Reinforced Polymers Laminates.
   b) Bonding Coats.
   c) Fiber reinforced concrete.
   d) Shear Connectors.

Question (3):

1) Answer the following questions:
   a) What are the main differences between ***crack injection*** and ***crack grouting*** techniques.
   b) Compare between the most used resins for crack injection in view of ***strength, hardening time and applications.***
   c) Give the differences between ***concrete replacement*** and ***jacketing*** techniques.
   d) State down the two types of ***injection points*** and the applicability of each type.
2) On a sketch for vertically arranged injection nipples, show the components used in crack injection technique and the direction of injection.
3) Choose the most suitable repair/strengthening technique for each of the following defects in concrete elements:
   a) Wide and very deep straight cracks
   b) Deep narrow cracks
   c) Limited number of very narrow cracks
   d) Insufficient stiffness
   e) Easy access of corrosive materials
   f) Large number of hair ceacks in RC slab

Question (4):

1) Using neat sketches only, explain the following:
   a) Examination of the activity of structural cracks in concrete elements
   b) Shape of joint after blanketing of active cracks with and without bond breaker.
   c) Both of rooting and sealing of cracks.
2) Explain, using neat sketches, the precautions to accommodate the movements of active cracks when using blanketting repair technique.
3) Explain, briefly, the main steps of vacuum polymer impregnation repair technique for narrow cracks in RC slabs.
4) A ground floor column in a residential building was affected by the deficiency in construction workmanship that manifests honycombing of the lower portion of the column. The field tests showed that the honycombing infiltrated through the entire cross section of the column. The figure illustrates the condition of the column. Suggest a remedy procedure for the column.



Good Luck

Ain Shams University
Faculty of Engineering
4th Year - Structural Engineering
Department

Repair and Strengthening of Structures
CES 441
December, 2006
Time Allowed : 3 hours

Atempet all Questions (The Exam. Consists of 4 Questions)

Question (1):

1. What are the differences between repair and strengthening of concrete structures. Draw relationships to show the effect of each of :
   repair – maintenance – protection
   on the service life of structures.

2. **Core and loading tests** were carried out for the evaluation of a reinforced concrete flat slab of thickness 25 cm and span 7 m (in both directions). **Tests** were carried out and the following results were obtained:
   a. Three cores of diameter 10 cm and height after capping 12.3 cm were drilled, and then tested in compression. Failure loads were 13 – 12.4 – 11.8 ton respectively. The required characteristic compressive strength of concrete after 28 days = 250 kg/cm^2.
   b. Loading test was carried out for the slab and deflections were recorded in three positions. Test results were as follows:

Position		1	2	3
Deflection (mm)	After 24 hours of loading	6.6	7.1	18.30
	After 24 hours of unloading	1.32	1.65	4.47

   i- Discuss the safety of the tested slab according to the requirements of the Egyptian Code for concrete structures.
   ii- **If** the tested slab failed to satisfy the requirements of the Egyptian Code for concrete structures, state the possible ways to make it safe.

3. Using neat sketches, discuss some applications for each of the following materials used in repair and strengthening works:
   a. Carbon Fiber Reinforced Polymers Laminates.
   b. Bonding Coats.
   c. Glass Fiber Reinforced Polymers Sheets.
   d. Shear Connectors.

Question (2):

1. Differentiate between each of the following techniques used for base concrete surface preparation:
   Push hammers – Water jetting – Sand blasting.

2. Define the term "compatibility". Discuss the compatibility of the following repair materials with base concrete?. Which one can be chosen as a suitable repair material for the repair of concrete floors of an industrial meat plant?

Mechanical or Physical Property	Base Concrete	Cementitious Material	Polymer modified Material	Resinous Material
Modulus of Elasticity (G.Pa)	20	25	20	15
Coefficient of Thermal Expansion ($C^{-1} \times 10^{-6}$)	11	10	13	28
Maximum Service Temperature (^oC)	200	> 300	200	60
Drying shrinkage (micro-strain)	-----	1500	600	150

   Discuss the effect of the use of each of the three repair materials on the predicted service life of the repaired structure.

3. Slant shear test was carried out to estimate the shear bond strength between new concrete and old base concrete. Four composite specimens of total dimensions 100 × 100 × 400 mm were cast and tested in compression. The angle of inclination of the interface to the horizontal surface was 60 ° with respect to the horizontal surface. Test results were as follow:

Test No.	Failure load (kN)	Mode of failure
1	180	Splitting
2	150	Sliding
3	160	Splitting
4	145	Sliding

a. Calculate the value of the average shear bond strength.
b. Using neat sketches, show the different obtained modes of failure.

Question (3):

1. Compare between each of the following:
   a. Injection and grouting repair techniques.
   b. Concrete replacement and concrete jacketting techniques.
   c. Wet process and dry process in the shotcrete technique.
   d. Configuration of strengthening RC columns using FRP strips for Flexural or FRP wraps for confinement.
2. What is the most common recommendation of the technical report for shotcrete repair technique which contradicts with the recommendations of the ACI Manual for this technique?. Write a list of the possible materials for use in shotcrete application technique.
3. Using neat sketches only, explain the following:
   a. Different geometries of RC jackets for concrete beams.
   b. External prestressing of RC beam to control existing bending cracks.
   c. Deep active crack in RC slab on grade repaired with and without bond breaker.
4. Give examples for the most common materials used in crack injection. Note down the desirable qualities for epoxy injection resins.

Question (4):

1. Choose the most suitable repair/strengthening technique for each of the following purposes:
   a. Rehabilitation of limited active cracks in RC road slab.
   b. Remedy of crazing of RC slab.
   c. Protecting steel reinforcement from access of corrossive media.
   d. Repair of surface inter-connected voids in RC column.
   e. Repair of deep inter-connected voids in RC abutments under water level.
2. Outline the basic features of the drypack repair technique. Explain the type of deteriaration to be repaired using this technique.
3. Sketch for the possible failure modes of a reinforced concrete member strengthened with carbon fiber laminates.
4. Compare between vacuum polymer impregnation repair technique and polymer injection technique for narrow cracks in RC slabs in view of: materials used, mechanism of air removal, value of applied pressure, and need for entry ports.

GOOD LUCK

1. state Down two types of injection points and the applica[tion] of each type

1- Nipples screw into Concrete — في حالة ان عرض الشرخ صغير
2- Holles Drilled on the line of the Crack → used in the wide cr[ack]
→ (External injection Nipples)

2.
b.

Concrete Replacement :- احلال خرسانة جديدة بدلاً من الخرسانة التالفة دون زيادة في قدرة تحمل العنصر الانشائي.

Jacketting :- تستخدم لزيادة قدرة تحمل العناصر الانشائية (اعمدة - كمرات - قواعد)

c) wet process :

مونة (اسمنت + رمل + ماء) مخلوطة بالموقع بنسبة 1 اسمنت : 4 رمل او تخلط يتم شراؤها من محطة الخلط يتم دفعها بقوة ضغط عالية وبالتالي لابد ان تكون قابلية تشغيل عالية

dry process :- يتم خلط المواد الجافة (الرمل والاسمنت) ويتم دفعهم بواسطة هواء مضغوط ويتم اضافة الماء لحظة الخروج

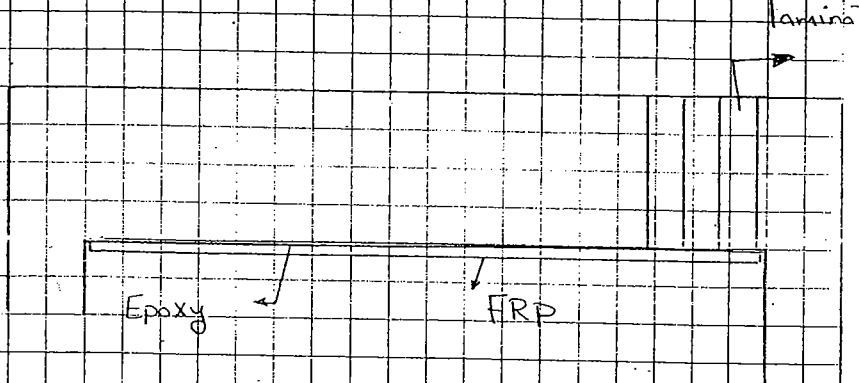
Difference between wet process , dry process

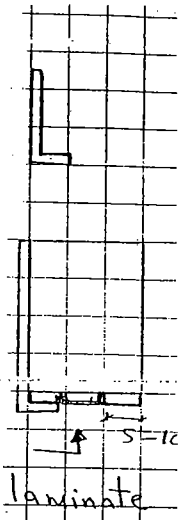
1) wet process needs High pressure , dry process need low pressure
2) the wet process has less Rebound, dust
3) dry process ينتج عنه غبرة بالجو
4) في wet process يتم استخدام اضافات وذلك لتقليل كمية الماء المستخدمة وذلك لتحقيق قابلية تشغيل اعلى و ↑ strength

↓ Shrinkage

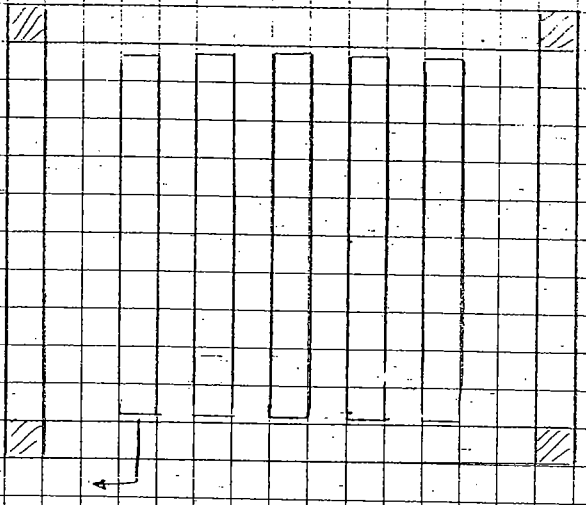
d) 1- Flexural member

- beam



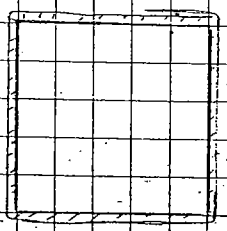


- slab

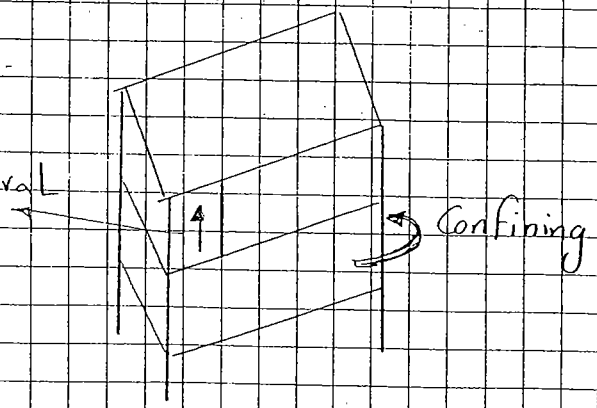


2- Columns

N - only

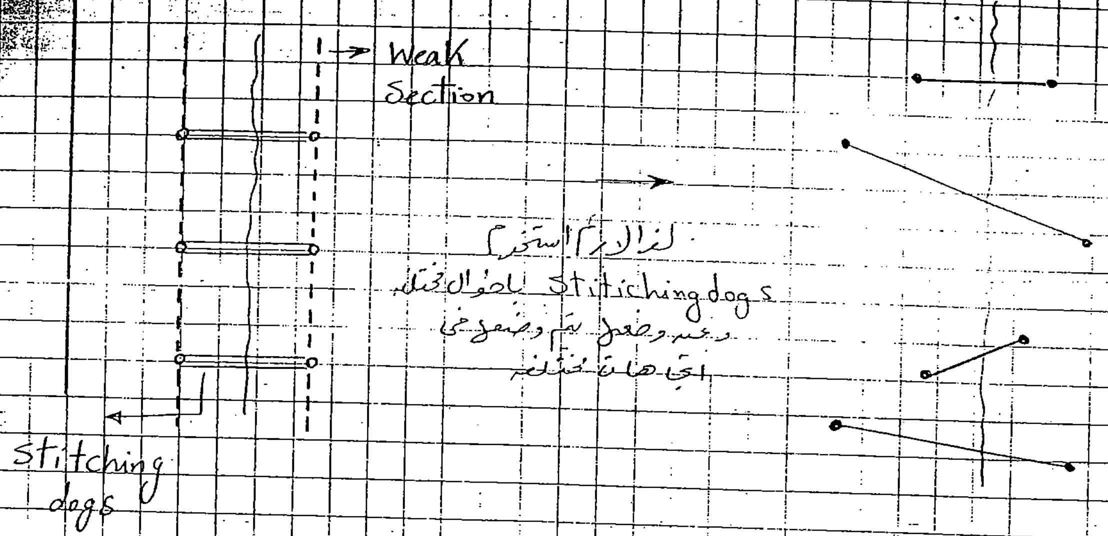


N - M

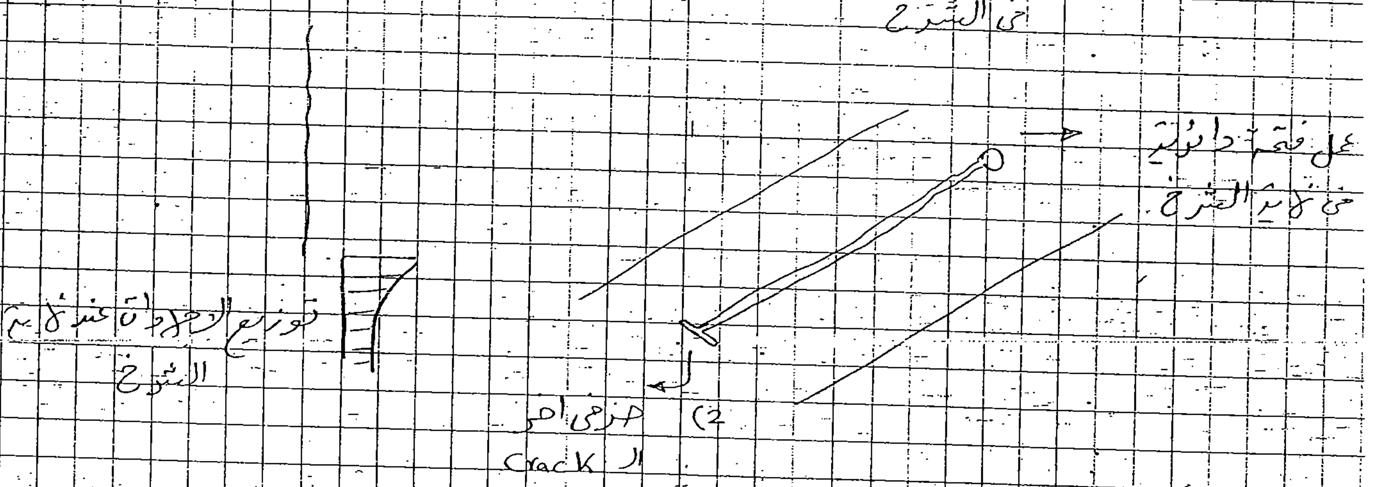


3.

1.

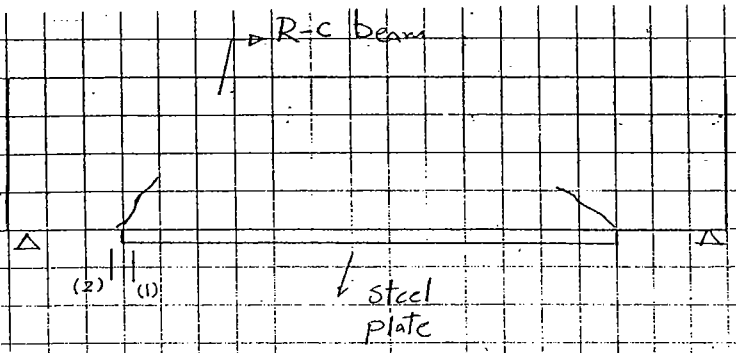


2. عند نهاية الشرخ بيكون هناك تركز اجهادات لذا نمنع استمرار في الشرخ



3. في حالة ان الشرخ عاوز يفتح هيولد اجهادات شد على stitching dogs فمفيش مشكلة لكن في حالة ان الشرخ عاوز يقفل هيولد اجهادات ضغط وبالتالي هيحدث buckling لذا عند التنفيذ يتم وضع ال stitching dogs بعمق 3 cm داخل الخرسانة وتغطى بلياسة اسمنتية لتثبيتها وايضا لحمايتها من الصدأ

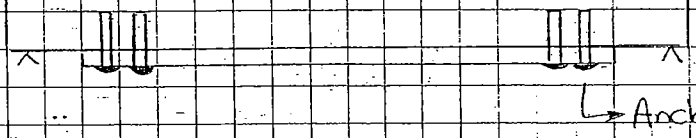
4-

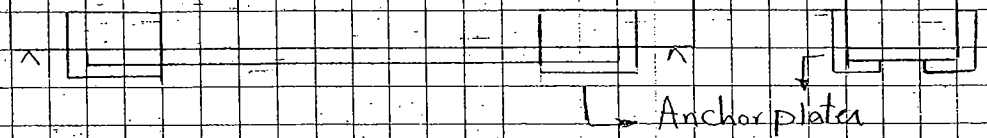


نتيجة ان Sec (1) حساسة اكثر بكثير من Sec (2) حيث ان

سببة Stress Conc عند نزول الـ plate عما يشرخ الخرسانة

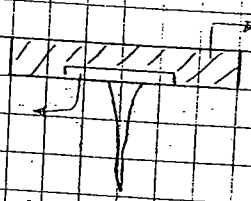
كل ما قوة نزول الـ plate حماية الخرسانة عند نزول الـ plate





a) Best Active Crack in R.C slab ongrade with bond breaker

الـ bond breaker هيعمل على قدد المادة العاطفية على طول طولة
عندها يتمدد الشرخ وبالتالى لم يكدش شروخ بالمادة العاطفية



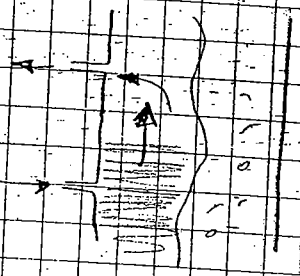
- Without bond breaker

الجزء المرجوح فرق الشرخ هو المادة العاطفية هو الذى سيتمدد وذلك
لان باقى المادة العاطفية متماسكة مع الخرسانة فسيؤدى لان اى حدوث
شرخ فى المادة العاطفية
وذلك لصعوبة وجود مادة عاطفية لها Ductility تتناسب مع
حركة الشرخ

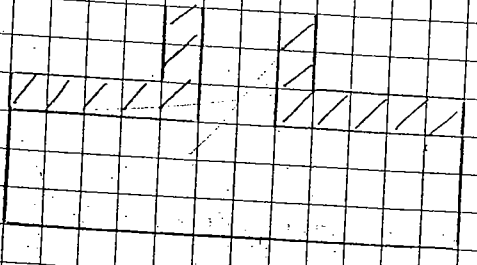
b)

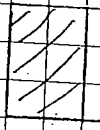
اكارة الحقن ساسيل لاعلى للتاكد من
امتلاء الشرخ بالكامل

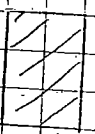
direction of injection



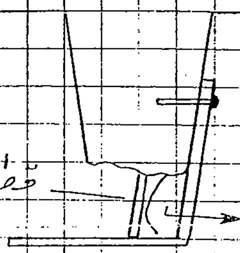
c) Unsafe Moment, Shear, Punching Contact Stress > allowable Bearing Cap







يتم وضع قطعة خشبية ع Dry mortar
يتم الطرق عليها حتى يخرج الماء
الزائد (طريقة الرمل
باستخدام (dryback method



2. a- External prestressing
   b- Rooting and sealing
   c- prepacked Agg. concrete "طريقة الركام المعبأ مسبقا"
   d- Bonded steel Elements , strengthening with FRP
   e- Dryback method
   f- Jacketing

3.
a. Removal of surface deteriorated concrete

1) احتياطيا كوش ماكون الطرق على إزاحة موازي لل Center line للعنصر الإنشائي
2) Sand blasting
3) Water Jetting
4) Pneumatic Tools
5) مواد حامضية

b. cleaning Reinf bars

1) فرشة سلك
2) Sand blasting

c-

D portland cement Grout :-
خلق وسط قاعدي حول التسليح وزيادة
تماسك الخرسانة القديمة والخرسانة الجديدة

2) Epoxy

Ain Shams University
Faculty of Engineering
4th Year - Structural Engineering Department

Repair and Strengthening of Structures
هدن ٤٢١ ج ف
June, 2006
Time Allowed : 3 hours

Atempet all Questions (The Exam. Consists of 4 Questions)

Question (1):

1- What is the difference between **rehabilitation** and **strengthening** of concrete structures. Using neat sketches only, discuss the different strengthening methods for concrete structures.

2- **Core** and **loading tests** were carried out for the evaluation of a reinforced concrete flat slab of thickness 25 cm and span 7 m (in both directions). Tests were carried out and the following results were obtained:

a- Three cores of diameter 10 cm and height after capping 12.3 cm were drilled, and then tested in compression. Failure loads were 13 – 12.4 – 11.8 ton respectively. The characteristic compressive strength of concrete after 28 days = 250 kg/cm^2.

b- Loading test was carried out for the slab and deflections were recorded in three positions. Test results were as follows:

Position		1	2	3
Deflection (mm)	After 24 hours of loading	6.6	7.1	18.30
	After 24 hours of unloading	1.32	1.65	4.47

i- Discuss the safety of the tested slab according to the requirements of the Egyptian Code for concrete structures.

ii- If the tested slab failed to verify the requirements of the Egyptian Code for concrete structures, state the possible ways to make it safe.

3- Discuss the effect of each of the following properties on the **compatibility** of new concrete to an old base concrete:

a- Early drying shrinkage and creep.
b- Modulus of elasticity.
c- Thermal expansion.
d- Poisson's ratio

Question (2):

1- Differentiate between each of the following techniques used for base concrete surface preparation:

Push hammers – Water jetting – Sand blasting.

2- Using neat sketches, discuss some applications for each of the following materials used in repair and strengthening works:

a- Carbon Fiber Reinforced Polymers Laminates.
b- Bonding Coats.
c- Glass Fiber Reinforced Polymers Sheets.
d- Shear Connectors.

3- What are the differences between each of **slant shear** and **tension pull-off** tests.

4- **Tension pull-off** test was carried out to estimate the bond strength between new concrete and old base concrete, four steel targets of diameter 70 mm were glued to repair surface using a suitable adhesive material. Test results were as follow:

Test No.	Failure load (kN)	Mode of failure
1	11.0	Base failure
2	10.0	Interface failure
3	11.5	Repair failure
4	10.5	Interface failure

a- Estimate each of tensile strength of base concrete and the average bond strength between the new and the old base concrete.

b- Using neat sketches, show the mode of failure for each test.

Question (3):

1. Explain with sketches the possible methods to apply the repair material to existing old concrete during the concrete replacement technique.
2. Mention the possible procedures to check the acceptance of injection technique.
3. What are the major defects that may be repaired using the application of FRP products. Explain, with sketches, the shape and location of FRP laminates in each case.
4. Using neat sketches only, explain the following:
   a. Different geometries of RC jackets for concrete columns.
   b. Shape of joint after blanketing of active cracks executed with and without bond breaker.
   c. Abutment for external prestressing of RC beam to control existing bending cracks.

Question (4):

1. Choose the most suitable repair/strengthening technique for each of the following defects in concrete elements:
   a. A single narrow crack in RC beam. → Brushing with latex emulsion
   b. A straight, deep, wide crack in RC wall. → drilling & plugging
   c. Map cracks in RC slab. Vacuum & Impregnation
   d. Surface inter-connected voids in RC column.
   e. Deep inter-connected voids in RC column.
2. Mention the required precautions to avoid the drawbacks of crack stitching technique.
3. Sketch the possible failure modes of a reinforced concrete member strengthened with carbon fibers.
4. Explain, briefly, the main steps of vacuum polymer impregnation repair technique for narrow cracks in RC slabs.

GOOD LUCK

Ain Shams University
Faculty of Engineering
4th Year - Structural Engineering
Department

Repair and Strengthening of Structures
Jan 2009
Time Allowed : 3 hours

Atempet all Questions (The Exam. Consists of 4 Questions)

Question (1):

1) What is the difference between **maintenance** and **protection** of concrete structures. Using neat sketches only, discuss the different strengthening methods for concrete structures using additional bonded materials.
2) What are the objectives of the evaluation of concrete structures. Discuss each of the following for the loading test carried out for a reinforced concrete cantiliver slab of free length = 2.0 m, thickness 20 cm, floor cover 150 = kg/cm^2, live load = 300 kg/cm^2 :
   a) Test load
   b) Test procedure
   c) Measurements
   d) Results obtained & final conclusion
3) Discuss the effect of each of the following properties on the compatibility of new concrete to an old base concrete:
   a) Early drying shrinkage and creep.
   b) Modulus of elasticity.
   c) Thermal expansion.
   d) Poisson's ratio

Question (2):

1) Rewrite each of the following statements and Put sign (√) or (X) beside each of them. If the statement is wrong; put it in the right form:
   a) In the majority of concrete structures, cracks result in structural failure. X
   b) ~~Repair~~ can be defined as to replace or correct deteriorated, damaged, or faulty materials, components, or elements of a structure. X
   c) Increasing the cross section of concrete column is more significant strengthening method than increasing the cross section of concrete beam. √
   d) Placing additional reinforcement in the tension zone of a reinforced concrete beam (protected by an additional concrete cover by shotcrete) is a very effective strengthening method. √
   e) In the case of structural repair, loaded in compression, the repair material must possess very high creep potential. X
   f) When selecting a non-structural repair material, designers should ensure that repair material has a higher value of modulus of elasticity than base concrete. X
   g) Cementitious based materials has similar coefficient of thermal expansion. √
   h) Creep of repair material increase stresses due to shrinkage at the interface between it and base concrete. X
2) Slant shear test was carried out to estimate the shear bond strength between new concrete and old base concrete. Four composite specimens of total dimensions 100 × 100 × 400 mm were cast and tested in compression. The angle of inclination of the interface to the horizontal surface was 60 ° with respect to the horizontal surface. Test results were as follow:

Test No.	Failure load (kN)	Mode of failure
1	180	Splitting
2	150	Sliding
3	160	Splitting
4	145	Sliding

   a) Calculate the value of the average shear bond strength.
   b) Using neat sketches, show the different obtained modes of failure.

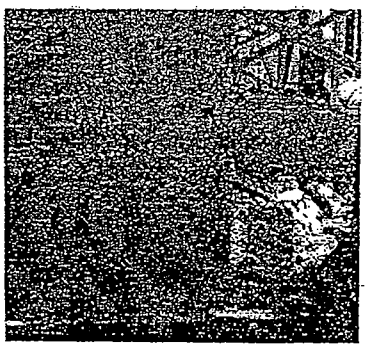
3) Using neat sketches, discuss some applications for each of the following repair and strengthening works:
   a) Carbon Fiber Reinforced Polymers Laminates.
   b) Bonding Coats.
   c) Fiber reinforced concrete.
   d) Shear Connectors.

Question (3):

1) Answer the following questions:
   a) What are the main differences between ***crack injection*** and ***crack grouting*** techniques.
   b) Compare between the most used resins for crack injection in view of ***strength, hardening time and applications.***
   c) Give the differences between ***concrete replacement*** and ***jacketing*** techniques.
   d) State down the two types of ***injection points*** and the applicability of each type.
2) On a sketch for vertically arranged injection nipples, show the components used in crack injection technique and the direction of injection.
3) Choose the most suitable repair/strengthening technique for each of the following defects in concrete elements:
   a) Wide and very deep straight cracks
   b) Deep narrow cracks
   c) Limited number of very narrow cracks
   d) Insufficient stiffness
   e) Easy access of corrosive materials
   f) Large number of hair ceacks in RC slab

Question (4):

1) Using neat sketches only, explain the following:
   a) Examination of the activity of structural cracks in concrete elements
   b) Shape of joint after blanketing of active cracks with and without bond breaker.
   c) Both of rooting and sealing of cracks.
2) Explain, using neat sketches, the precautions to accommodate the movements of active cracks when using blanketting repair technique.
3) Explain, briefly, the main steps of vacuum polymer impregnation repair technique for narrow cracks in RC slabs.
4) A ground floor column in a residential building was affected by the deficiency in construction workmanship that manifests honycombing of the lower portion of the column. The field tests showed that the honycombing infiltrated through the entire cross section of the column. The figure illustrates the condition of the column. Suggest a remedy procedure for the column.



Good Luck

Ain Shams University	**Repair and Strengthening of Structures**
Faculty of Engineering	**CES 441**
4th Year - Structural Engineering	**December, 2006**
Department	**Time Allowed : 3 hours**

Atempet all Questions (The Exam. Consists of 4 Questions)

Question (1):

1. What are the differences between repair and strengthening of concrete structures. Draw relationships to show the effect of each of :

   repair – maintenance – protection

   on the service life of structures.

2. **Core and loading tests** were carried out for the evaluation of a reinforced concrete flat slab of thickness 25 cm and span 7 m (in both directions). Tests were carried out and the following results were obtained:
   a. Three cores of diameter 10 cm and height after capping 12.3 cm were drilled, and then tested in compression. Failure loads were 13 – 12.4 – 11.8 ton respectively. The required characteristic compressive strength of concrete after 28 days = 250 kg/cm^2.
   b. Loading test was carried out for the slab and deflections were recorded in three positions. Test results were as follows:

Position		1	2	3
Deflection (mm)	After 24 hours of loading	6.6	7.1	18.30
	After 24 hours of unloading	1.32	1.65	4.47

   i- Discuss the safety of the tested slab according to the requirements of the Egyptian Code for concrete structures.

   ii- **If** the tested slab failed to satisfy the requirements of the Egyptian Code for concrete structures, state the possible ways to make it safe.

3. Using neat sketches, discuss some applications for each of the following materials used in repair and strengthening works:
   a. Carbon Fiber Reinforced Polymers Laminates.
   b. Bonding Coats.
   c. Glass Fiber Reinforced Polymers Sheets.
   d. Shear Connectors.

Question (2):

1. Differentiate between each of the following techniques used for base concrete surface preparation:

   Push hammers – Water jetting – Sand blasting.

2. Define the term "compatibility". Discuss the compatibility of the following repair materials with base concrete?. Which one can be chosen as a suitable repair material for the repair of concrete floors of an industrial meat plant?

Mechanical or Physical Property	Base Concrete	Cementitious Material	Polymer modified Material	Resinous Material
Modulus of Elasticity (G.Pa)	20	25	20	15
Coefficient of Thermal Expansion ($C^{-1} \times 10^{-6}$)	11	10	13	28
Maximum Service Temperature (°C)	200	> 300	200	60
Drying shrinkage (micro-strain)	-----	1500	600	150

Discuss the effect of the use of each of the three repair materials on the predicted service life of the repaired structure.

3. Slant shear test was carried out to estimate the shear bond strength between new and old base concrete. Four composite specimens of total dimensions 100 × 100 × 400 mm were cast and tested in compression. The angle of inclination of the interface to the horizontal surface was 60 ° with respect to the horizontal surface. Test results were as follow:

Test No.	Failure load (kN)	Mode of failure
1	180	Splitting
2	150	Sliding
3	160	Splitting
4	145	Sliding

a. Calculate the value of the average shear bond strength.
b. Using neat sketches, show the different obtained modes of failure.

Question (3):

1. Compare between each of the following:
   a. Injection and grouting repair techniques.
   b. Concrete replacement and concrete jacketting techniques.
   c. Wet process and dry process in the shotcrete technique.
   d. Configuration of strengthening RC columns using FRP strips for Flexural or FRP wraps for confinement.
2. What is the most common recommendation of the technical report for shotcrete repair technique which contradicts with the recommendations of the ACI Manual for this technique?. Write a list of the possible materials for use in shotcrete application technique.
3. Using neat sketches only, explain the following:
   a. Different geometries of RC jackets for concrete beams.
   b. External prestressing of RC beam to control existing bending cracks.
   c. Deep active crack in RC slab on grade repaired with and without bond breaker.
4. Give examples for the most common materials used in crack injection. Note down the desirable qualities for epoxy injection resins.

Question (4):

1. Choose the most suitable repair/strengthening technique for each of the following purposes:
   a. Rehabilitation of limited active cracks in RC road slab. → Latex
   b. Remedy of crazing of RC slab. MP
   c. Protecting steel reinforcement from access of corrossive media. rooting and Sel
   d. Repair of surface inter-connected voids in RC column.
   e. Repair of deep inter-connected voids in RC abutments under water level.
2. Outline the basic features of the drypack repair technique. Explain the type of deteriaration to be repaired using this technique.
3. Sketch for the possible failure modes of a reinforced concrete member strengthened with carbon fiber laminates.
4. Compare between vacuum polymer impregnation repair technique and polymer injection technique for narrow cracks in RC slabs in view of: materials used, mechanism of air removal, value of applied pressure, and need for entry ports.

GOOD LUCK

Answer the Following Questions
(The Exam. Consists of 8 Questions)

Question (1):

a- Draw relationships show the effect of each of :
repair – maintenance – protection
on the service life of structures.

b- What are the objectives of the evaluation of concrete structures. State three different methods used for in-situ evaluation of concrete structures.

c- For the evaluation of a reinforced concrete cantilever flat slab of thickness 20 cm and free span 2.25 m, loading test was carried out for the slab and deflections at the free end were recorded. Test results were as follows:

Position		1	2	3
Deflection (mm)	After 24 hours of loading	4.5	5.0	3.7
	After 24 hours of unloading	3.5	2.6	1.5

a) Discuss the safety of the tested slab according to the requirements of the Egyptian Code for concrete structures.

Question (2):

a- Define the term "compatibility".

b- Discuss the compatibility of the following repair materials with base concrete?. Which material can be chosen as a suitable repair material for the repair of concrete floors of an industrial meat plant?

Mechanical or Physical Property	Base Concrete	Cementitious Material	Polymer modified Material	Resinous Material
Modulus of Elasticity (G.Pa)	20	25	20	15
Coefficient of Thermal Expansion ($C^{-1} \times 10^{-6}$)	11	10	13	28
Maximum Service Temperature (°C)	200	> 300	200	60
Drying shrinkage (micro-strain)	-----	1500	600	150

Discuss the effect of the use of each of the three repair materials on the predicted service life of the repaired structure.

Faculty of Engineering — Design and Engineering of Structures — هندسة إنشاءات

4th Year - Structural Engineering — 2nd Term Exam. (May, 2005)

Department — Time Allowed : 3 hours

Question (3):

Put sign (√) or (X) beside each of the following statements. If the statement is wrong; put it in the right form:

1- Repair can be defined as to replace or correct deteriorated, damaged, or faulty materials, components, or elements of a structure. X

2- Increasing the cross section of concrete beam is more significant strengthening method than increasing the cross section of concrete column. √

3- Placing additional carbon fiber reinforced laminates in the tension zone of a reinforced concrete beam subjected to high temperatures is a very effective strengthening method. √

4- In the case of non-structural repair, loaded in compression, the repair material must possess very high creep potential. X

5- When selecting a structural repair material, designers should ensure that repair material has a higher value of modulus of elasticity than base concrete. √

6- In repair works, the effect of Poisson's ratio is lower when the bond interface is perpendicular to the direction of loading and negligible when the load is parallel to the interface. √

7- Adding silica fume to repair mortars reduces rebound during shotcreting. √

8- Cementitious based materials has similar coefficient of thermal expansion. √

9- Creep of repair material increase stresses due to shrinkage at the interface between it and base concrete. X

10- Carbon fiber sheets increase the load carrying capacity of reinforced concrete columns due to the increase of confinement. √

Question (4):

Core pull-off test was carried out to estimate the bond strength between repair mortar and base concrete, four steel targets of diameter 50 mm were glued to repair surface using a suitable adhesive material. Test results were as follow:

Test No.	Failure load (kN)	Mode of failure
1	6.0	Base failure
2	5.2	Interface failure
3	4.9	Repair failure
4	6.4	Interface failure

i- Estimate each of tensile strength of base concrete and the average bond strength between repair mortar and substrate concrete.

ii- Using neat sketches show the mode of failure for each test.

Ain Shams University
Faculty of Engineering
4th Year - Structural Engineering Department

Repair and Strengthening of ...
هلن ٤٢١ ج ف
2nd Term Exam. (May, 2005)
Time Allowed : 3 hours

Question (5):

1. Choose the most suitable repair/strengthening technique for each of the following defects in concrete elements:
   a. Wide and very deep straight cracks. b. Deep narrow cracks. c. Limited number of very narrow cracks. d. Insufficient stiffness. e. Easy access of corrosive materials. f. Large number of hair ceacks in RC slab
2. Compare between Wet proccess and Dry proccess methods used in shotcrete repair technique.
3. Explain, briefly, the main steps of crack injection repair technique for narrow cracks in RC elements.

Question (6):

1. Mention the required precautions to avoid the drawbacks of crack stitching technique.
2. What are the main differences between *crack injection* and *crack grouting* techniques.
3. Mention the necessary materials and tools used in the method of concrete replacement.

Question (7):

1. Using neat sketches only, explain the following:
   a. Examination of the *activity* of structural cracks in concrete elements
   b. Shape of joint after blanketing of active cracks *with* and *without* bond breaker.
   c. Both of *rooting* and *sealing* of cracks.
2. Mention four methods for the application of repair material in the concrete replacement technique.
3. *Sketch* for the possible failure modes of a reinforced concrete member strengthened by carbon fibers.

Question (8):

1. What are the methods, commonly used, for bonding of external steel plates to the bottom of RC beam.
2. State down the major definition for both of *"Dry back"* and *"Prepacked aggregate concrete"* repair techniques.
3. Give the differences between concrete replacement and jacketing techniques.

GOOD LUCK

AIN SHAMS UNIVERSITY
FACULTY OF ENGINEERING
STRUCTURAL ENGINEERING DEPARTMENT
4th Year Structural Engineering

1st Semester, 2010-2011 Course Code: *CES 441* *Time : 3.00 Hrs*

Repair and Strengthening of Structures

The Exam Consists of **Four** Questions in **Two** Pages *Total Marks: 70 Marks* 1/2

Question (1): (25%)

a- What are the differences between **repair** and **strengthening** of concrete structures. State briefly with clear sketches the different strengthening methods for concrete structures.

b- What are the objectives of the evaluation of concrete structures. Describe using clear sketches **three** different methods used for in situ evaluation of concrete structures.

c- Define the term "**compatibility**".

d- Discuss the compatibility of the following repair mortars with base concrete?. Which one can be chosen as a suitable repair material for an industrial building? Give your reasons.

Mechanical or Physical Property	Base concrete	Cementitious Mortar	Polymer modified Mortar	Resinous Mortar
Modulus of Elasticity (G.Pa)	20	25	20	15
Coefficient of Thermal Expansion ($C^{-1} \times 10^{-6}$)	11	10	13	28
Maximum Service Temperature (°C)	200	> 300	200	60
Drying shrinkage (micro-strain)	-----	1500	600	150

Question (2): (25%)

a- Differentiate between each of the following techniques used for base concrete surface preparation:

Push hammers – Water jetting – Sand blasting

b- *"During the evaluation of a reinforced concrete structure it was concluded that some reinforced concrete columns in the basement floor need strengthening."* state and explain briefly possible methods can be used for the strengthening of these elements (columns).

c- Outline with clear sketches test set-up for each of **slant shear** and **pull-off** tests of bond between repair materials and base concrete.

d- **Tension core pull-off** test was carried out to estimate the bond strength between repair mortar and base concrete, four steel targets of diameter 50 mm were glued to repair surface using a suitable adhesive material. Test results were as follow:

Test No.	Failure load (kN)	Mode of failure
1	7.0	Base failure
2	6.3	Interface failure
3	7.4	Base failure
4	5.5	Repair failure

i) Estimate each of tensile strength of base concrete and the average bond strength between repair mortar and substrate concrete.

ii) Using neat sketches, show the mode of failure for each test.

AIN SHAMS UNIVERSITY, FACULTY OF ENGINEERING
STRUCTURAL ENGINEERING DEPARTMENT

4th Year Structural Engineering

1st Semester, 2010-2011 Course Code: *CES 441* *Time : 3.00 Hrs*

Repair and Strengthening of Structures

The Exam Consists of *Four* Questions in *Two* Pages *Total Marks: 70 Marks* 2/2

Question (3): (25%)

1. State down the two types of injection points and the applicability of each type.
2. Compare between each of the following:
   a. Injection and grouting repair techniques.
   b. Concrete replacement and jacketting techniques.
   c. Wet process and dry process in the shotcrete technique.
   d. Configuration of FRP strips for flexural or confinement reinforcing in RC columns.
3. In a tabulated form, illustrate the major drawbacks of stitching repair technique and the corresponding precautions to overcome them.
4. What are the problems associated with the technique of bonded steel plates used for repairing RC beams? On sketches, show how these problems may be solved

Question (4): (25%)

1. Using neat sketches only, explain the following:
   a. Deep active crack in RC slab on grade repaired with and without bond breaker
   b. Arrangement of injection nipples along a vertical crack showing the direction of injection
   c. Different schemes of strengthening isolated RC footing using the jacketing technique
   d. Method of compaction followed in the drypack method
2. Choose the most suitable repair/strengthening technique for each of the following defects in concrete elements:
   a. Deep inter-connected cracks in RC beam
   b. Easy access of corrosive materials
   c. Repair of deep inter-connected voids in RC abutments under water level
   d. Doubling the load carrying capacity of RC columns
   e. Thorough holes in RC walls
   f. Bending cracks in an isolated RC footing
3. Mention the possible alternatives used for each of the following processes in concrete replacement repair technique:
   a. Removal of surface deteriorated concrete
   b. Cleaning of rusted reinforcing bars
   c. Enhancing the bond between old and new concrete

Best Wishes

Ain Shams University
Faculty of Engineering
4th Year - Structural Engineering Department

Repair and Strengthening of Structures

January, 2010
Time Allowed : 3 hours

Atempet all Questions (The Exam. Consists of 4 Questions)

Question (1):

1. What are the differences between rehabilitation and strengthening of concrete structures. Using neat sketches only, discuss the different strengthening methods for reinforced concrete columns.
2. *"In the majority of concrete structures, cracks do not result in structural failure, but they can result in definite loss of performance of structures".*

   Discuss this statement. Using clear skeches, show the crack pattern due to each of the following:

   Over loading for R.C beams – Settlement of plastic concrete in forms – Alkali Silica Reaction.
3. What are the objectives of the evaluation of concrete structures. Discuss each of the following for loading test carried out to evaluate a reinforced concrete flat slab with span 7m in long direction and 5m in short direction given that:

   slab thickness = 25 cm, floor cover load =150 kg/m^2, live load = 500 kg/m^2.

   a. Test load
   b. Test procedure
   c. Measurements
   d. Results obtained & final conclusion
4. Define the term "compatibility".Discuss the compatibility of the following repair materials with base concrete?. Which one can be chosen as a suitable repair material for the repair of concrete floors of an industrial meat plant. Give your reasons.

Mechanical or Physical Property	Base concrete	Cementitious Material	Polymer modified Material	Resinous Material
Modulus of Elasticity (G.Pa)	20	25	20	15
Coefficient of Thermal Expansion ($C^{-1} \times 10^{-6}$)	11	10	13	28
Maximum Service Temperature (°C)	200	>300	200	60
Drying shrinkage (micro-strain)	-----	1500	600	150

Question (2):

1. Torsion pull-off test was carried out to estimate the shear bond strength between a polymer modified repair mortar and base concrete. Four steel targets of diameter 50 mm were glued to repair mortar surface using a suitable adhesive material. Test results were as follow:

Test No.	Torsional moment at failure (N.mm)	Mode of failure
1	260	Substrate failure
2	230	Interface failure
3	280	Substrate failure
4	240	Interface failure

   a. Estimate each of the torsional shear strength of base concrete and the average shear bond strength between repair mortar and base concrete.
   b. Using neat sketches, show the mode of failure for each test. Give your comments.

Ain Shams University
Faculty of Engineering
4th Year - Structural Engineering Department

Repair and Strengthening of Structures

January, 2010
Time Allowed : 3 hours

2. What are the differences between direct loading bond tests and patch tests for repair works. Discuss test method carried out to estimate the bond strength between carbon fiber reinforced polymers (CFRP) and substrate concrete.

3. Explain the main factors affect the bond strength between repair materials and substrate concrete. Differentiate between each of the following techniques for base concrete surface preparation:

Push hammers – Water jetting – Sand blasting

Question (3):

1. Mention the different methods to repair concrete cracks of both active and dormant types. Explain the suitability of each method

2. In case of using internal injection nipples, what are the requirements for the nipple configuration and for the fixing procedure?

3. Note down the advantages of vacum polymer impregnation method compared with traditional pressure injection method to seal very narrow cracks in RC elements

4. Mention the different materials and tools necessary for concrete replacement technique

5. Explain with sketches the possible methods to apply the repair material to existing old concrete in the concrete replacement technique

Question (4):

1. Using neat sketches only, explain the following:
   a. Different geometries of RC jackets for concrete beams
   b. The technique of form and cast in the concrete replacement repair method
   c. Method of compaction followed in the drypack method
   d. Mechanizm of air removal during epoxy injection technique

2. Choose the most suitable repair/strengthening technique for each of the following defects in concrete elements:
   a. A single narrow crack in RC beam.
   b. A straight, deep, wide crack in RC wall.
   c. Map cracks in RC slab.
   d. Surface inter-connected voids in RC column.
   e. Bending cracks in an isolated RC footing.
   f. Splitting crack in RC column.

3. What are the problems associated with the technique of bonded steel plates used for repairing RC beams? On sketches, show how these problems may be solved

4. Explaining the technique on sketches, what are the items to be checked while applying the span shortening technique for strengthening flexural members? Also, how can we take advantage of the moving prob which may be used in this technique? What are the possible alternatives for the intermediate support?

Good Luck

Ain Shams University
Faculty of Engineering
4th Year - Structural Engineering
Department

Repair and Strengthening of Structures

Jan 2009

Time Allowed : 3 hours

Atempet all Questions (The Exam. Consists of 4 Questions)

Question (1):

1) What is the difference between maintenance and protection of concrete structures. Using neat sketches only, discuss the different strengthening methods for concrete structures using additional bonded materials.

2) What are the objectives of the evaluation of concrete structures. Discuss each of the following for the loading test carried out for a reinforced concrete cantiliver slab of free length = 2.0 m, thickness 20 cm, floor cover 150 = kg/cm^2, live load = 300 kg/cm^2 :

a) Test load
b) Test procedure
c) Measurements
d) Results obtained & final conclusion

3) Discuss the effect of each of the following properties on the compatibility of new concrete to an old base concrete:

a) Early drying shrinkage and creep.
b) Modulus of elasticity.
c) Thermal expansion.
d) Poisson's ratio

Question (2):

1) Rewrite each of the following statements and Put sign (√) or (X) beside each of them. If the statement is wrong; put it in the right form:

a) In the majority of concrete structures, cracks result in structural failure.
b) Repair can be defined as to replace or correct deteriorated, damaged, or faulty materials, components, or elements of a structure.
c) Increasing the cross section of concrete column is more significant strengthening method than increasing the cross section of concrete beam.
d) Placing additional reinforcement in the tension zone of a reinforced concrete beam (protected by an additional concrete cover by shotcrete) is a very effective strengthening method.
e) In the case of structural repair, loaded in compression, the repair material must possess very high creep potential.
f) When selecting a non-structural repair material, designers should ensure that repair material has a higher value of modulus of elasticity than base concrete.
g) Cementitious based materials has similar coefficient of thermal expansion.
h) Creep of repair material increase stresses due to shrinkage at the interface between it and base concrete.

2) Slant shear test was carried out to estimate the shear bond strength between new concrete and old base concrete. Four composite specimens of total dimensions 100 × 100 × 400 mm were cast and tested in compression. The angle of inclination of the interface to the horizontal surface was 60 ° with respect to the horizontal surface. Test results were as follow:

Test No.	Failure load (kN)	Mode of failure
1	180	Splitting
2	150	Sliding
3	160	Splitting
4	145	Sliding

a) Calculate the value of the average shear bond strength.
b) Using neat sketches, show the different obtained modes of failure.

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Repair and Strengthening of Structures

Jan 2009
Time Allowed : 3 hours

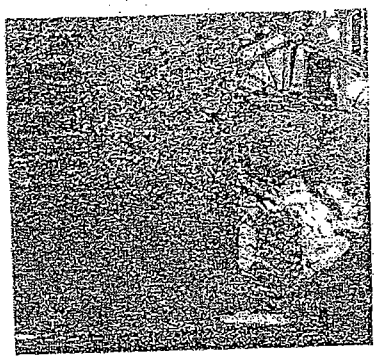
3) Using neat sketches, discuss some applications for each of the following materials used in repair and strengthening works:
   a) Carbon Fiber Reinforced Polymers Laminates.
   b) Bonding Coats.
   c) Fiber reinforced concrete.
   d) Shear Connectors.

Question (3):

1) Answer the following questions:
   a) What are the main differences between *crack injection* and *crack grouting* techniques.
   b) Compare between the most used resins for crack injection in view of *strength, hardening time and applications.*
   c) Give the differences between *concrete replacement* and *jacketing* techniques.
   d) State down the two types of *injection points* and the applicability of each type.
2) On a sketch for vertically arranged injection nipples, show the components used in crack injection technique and the direction of injection.
3) Choose the most suitable repair/strengthening technique for each of the following defects in concrete elements:
   a) Wide and very deep straight cracks
   b) Deep narrow cracks
   c) Limited number of very narrow cracks
   d) Insufficient stiffness
   e) Easy access of corrosive materials
   f) Large number of hair ceacks in RC slab

Question (4):

1) Using neat sketches only, explain the following:
   a) Examination of the activity of structural cracks in concrete elements
   b) Shape of joint after blanketing of active cracks with and without bond breaker.
   c) Both of rooting and sealing of cracks.
2) Explain, using neat sketches, the precautions to accommodate the movements of active cracks when using blanketting repair technique.
3) Explain, briefly, the main steps of vacuum polymer impregnation repair technique for narrow cracks in RC slabs.
4) A ground floor column in a residential building was affected by the deficiency in construction workmanship that manifests honycombing of the lower portion of the column. The field tests showed that the honycombing infiltrated through the entire cross section of the column. The figure illustrates the condition of the column. Suggest a remedy procedure for the column.



Good Luck

Ain Shams University
Faculty of Engineering
4th Year - Structural Engineering
Department

Repair and Strengthening of Structures
CES 441
December, 2006
Time Allowed : 3 hours

Atempet all Questions (The Exam. Consists of 4 Questions)

Question (1):

1. What are the differences between repair and strengthening of concrete structures. Draw relationships to show the effect of each of :
   repair – maintenance – protection
   on the service life of structures.
2. **Core and loading tests** were carried out for the evaluation of a reinforced concrete flat slab of thickness 25 cm and span 7 m (in both directions). Tests were carried out and the following results were obtained:
   a. Three cores of diameter 10 cm and height after capping 12.3 cm were drilled, and then tested in compression. Failure loads were 13 – 12.4 – 11.8 ton respectively. The required characteristic compressive strength of concrete after 28 days = 250 kg/cm^2.
   b. Loading test was carried out for the slab and deflections were recorded in three positions. Test results were as follows:

Position		1	2	3
Deflection (mm)	After 24 hours of loading	6.6	7.1	18.30
	After 24 hours of unloading	1.32	1.65	4.47

   i- Discuss the safety of the tested slab according to the requirements of the Egyptian Code for concrete structures.
   ii- If the tested slab failed to satisfy the requirements of the Egyptian Code for concrete structures, state the possible ways to make it safe.
3. Using neat sketches, discuss some applications for each of the following materials used in repair and strengthening works:
   a. Carbon Fiber Reinforced Polymers Laminates.
   b. Bonding Coats.
   c. Glass Fiber Reinforced Polymers Sheets.
   d. Shear Connectors.

Question (2):

1. Differentiate between each of the following techniques used for base concrete surface preparation:
   Push hammers – Water jetting – Sand blasting.
2. Define the term "compatibility". Discuss the compatibility of the following repair materials with base concrete?. Which one can be chosen as a suitable repair material for the repair of concrete floors of an industrial meat plant?

Mechanical or Physical Property	Base Concrete	Cementitious Material	Polymer modified Material	Resinous Material
Modulus of Elasticity (G.Pa)	20	25	20	15
Coefficient of Thermal Expansion ($C^{-1} \times 10^{-6}$)	11	10	13	28
Maximum Service Temperature (^{o}C)	200	> 300	200	60
Drying shrinkage (micro-strain)	-----	1500	600	150

   Discuss the effect of the use of each of the three repair materials on the predicted service life of the repaired structure.

3. Slant shear test was carried out to estimate the shear bond strength between new concrete and old base concrete. Four composite specimens of total dimensions 100 × 100 × 400 mm were cast and tested in compression. The angle of inclination of the interface to the horizontal surface was 60 ° with respect to the horizontal surface. Test results were as follow:

Test No.	Failure load (kN)	Mode of failure
1	180	Splitting
2	150	Sliding
3	160	Splitting
4	145	Sliding

a. Calculate the value of the average shear bond strength.
b. Using neat sketches, show the different obtained modes of failure.

Question (3):

1. Compare between each of the following:
   a. Injection and grouting repair techniques.
   b. Concrete replacement and concrete jacketting techniques.
   c. Wet process and dry process in the shotcrete technique.
   d. Configuration of strengthening RC columns using FRP strips for Flexural or FRP wraps for confinement.
2. What is the most common recommendation of the technical report for shotcrete repair technique which contradicts with the recommendations of the ACI Manual for this technique?. Write a list of the possible materials for use in shotcrete application technique.
3. Using neat sketches only, explain the following:
   a. Different geometries of RC jackets for concrete beams.
   b. External prestressing of RC beam to control existing bending cracks.
   c. Deep active crack in RC slab on grade repaired with and without bond breaker.
4. Give examples for the most common materials used in crack injection. Note down the desirable qualities for epoxy injection resins.

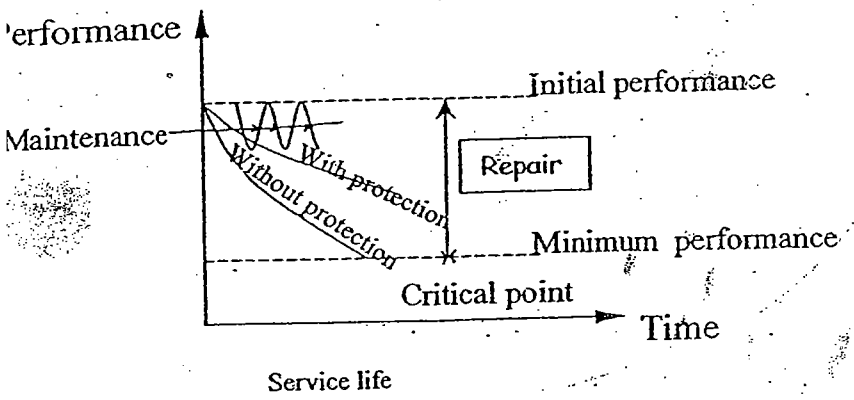
Question (4):

1. Choose the most suitable repair/strengthening technique for each of the following purposes:
   a. Rehabilitation of limited active cracks in RC road slab.
   b. Remedy of crazing of RC slab.
   c. Protecting steel reinforcement from access of corrossive media.
   d. Repair of surface inter-connected voids in RC column.
   e. Repair of deep inter-connected voids in RC abutments under water level.
2. Outline the basic features of the drypack repair technique. Explain the type of deteriaration to be repaired using this technique.
3. Sketch for the possible failure modes of a reinforced concrete member strengthened with carbon fiber laminates.
4. Compare between vacuum polymer impregnation repair technique and polymer injection technique for narrow cracks in RC slabs in view of: materials used, mechanism of air removal, value of applied pressure, and need for entry ports.

GOOD LUCK

REVISION

Repair and Strengthening of Concrete Structures



- نتيجة تعرض المنشا للعوامل المحيطة تقل ادائية النشأ مع الزمن
- عند الوصول الى Minimum performance يكون النشأ غير آمن و يجب عمل ترميم له .

تعريفات هامة :

- الادائية " Performance "
- النقطة الحرجة " critical point "
- الترميم " Repair " ← إعادة المقاومة .
- اعادة التأهيل = الاصلاح " Rehabilitation "
- التدعيم " strengthening " ← زيادة المقاومة .
- الحماية " protection "
- الصيانة " Maintenance "
- عمر المنشأ " service life "

---

* اسباب حدوث العيوب بالمنشآت الخرسانية .. rioration of concrete structure

١- مشكلة فى التصميم .
٢- " " التنفيذ .
٣- اهمال فى العزل الحرارى و المائى .
٤- تعرض المنشأ لعوامل لم تؤخذ فى الاعتبار عند التصميم

* خاصة بجب عمل تقييم للمنشآت الخرسانية

Evaluation of concrete structure : تقييم المنشآت الخرسانية ⟸

١- الاختبارات الغير متلفة للخرسانة

أ- اختبار الصلادة (بطريقة الارتداد) Rebound Hammer

ب- " الموجات فوق الصوتية Ultrasonic-Pulse-Velocity (U.P.V)

ج- الاختبارات قليلة الاتلاف (محدودة الاتلاف)

أ- اختبار القلب الخرساني (Core test)

٢- الاختبارات المتلفة للخرسانة

أ- اختبار تحميل العناصر والمنشآت الخرسانية (Loading test)

⟸ يجب الاهتمام بالتدريب على كيفية حل المسائل على هذه الاختبارات

* بالاضافة الى
- معاينة الميدان (الفحص البصري).
- مراجعة التصميم الانشائي.

Repair and strengthening materials
مواد الترميم و التدعيم

* العوامل التي يعتمد عليها اختيار مواد الترميم والتدعيم:-
- تكلفة ترميم المنشأ.
- طبيعة المواد المستخدمة والخواص الواجب توافرها فيها.
- طبيعة المنشأ وطرق استخدامه.

(1- Repair material)

(1) Cementitious material.
(2) Modified Cementitious material.
(3) Resinous material

Ultra Sonic

* يجب أن يكون بين مادة الترميم والخرسانة القديمة
(Compatibility) ١- توافق الخواص بين الحادثين
(Bond strength) ٢- تماسك بينهما

1- Compatibility ← توافق

- Physical compatibility
- 2- Chemical Compatibility
- 3- Electro chemical Compatibility
- 4- Permeability

Dry shrinkage → (يفضل استخدام مواد ترميم يكون انكماشها منخفض)

Thermal Expansion → ($\alpha_{repair\ material} \simeq \alpha_{old\ concrete}$)

* معامل التمدد الحراري (α) : مقدار التمدد والانكماش الذي يحدث في المادة عند ارتفاع وانخفاض درجة الحرارة.

Creep → (الزحف : زيادة التشكل مع ثبات الحمل)

Modulus of Elasticity (E) → (نسبة التغير في الاجهاد الى التغير في الانفعال)

$$E_{Repair\ mat.} \simeq E_{old\ concrete}$$

Poisson's ratio (Poissoms ratio)
- (نسبة الانفعال العرضي الى الانفعال الطولي)
- كلما ضعفت مقاومة الخرسانة زادت نسبة بواسون (μ)

$\mu_{repair\ material}$ ⇓

2- Bond strength

* العوامل المؤثرة على التماسك بين مادة الترميم والخرسانة القديمة.
* الاحتياطات الواجب مراعاتها للحصول على تماسك جيد بين مادة الترميم والخرسانة القديمة

١- دراسة خواص مادة الترميم
٢- تجهيز سطح الخرسانة القديمة (عمل زنبرة وتخشين السطح)
((Push hammer / sand blast / water Jetting))
٣- اجراء عملية الترميم بطريقة فنية سليمة
٤- استخدام مواد لتحسين التماسك
((Bonding Coats / Shear Connectors))

* لتقييم التلاصق بين مادة الترميم و الخرسانة القديمة

1- slant shear test ((اختبار القص المائل))

2- Pull-off test

2- strengthening materials

* concrete
* steel
* FRP ((Fiber Reinforced Polymer Plastics)) < CFRP / GFRP

---

aterial	E (GPa)	Compression strength (MPa)	Tensile strength (MPa)	γ (kg/m³)
ncrete	20 - 40	5 - 60	1 - 3	2400
teel	200 - 210	240 - 690	240 - 690	7800
FRP	200 - 800	No value is avaliable	2500 - 7500	1750 - 1950

* MPa $\xrightarrow{*10^6}$ Pa = N/m²

GPa $\xrightarrow{*10^9}$ Pa = N/m²

* N $\xrightarrow{\div 10}$ kg

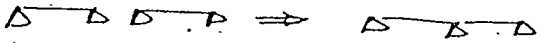
m $\xrightarrow{*100}$ cm

strengthening methods

without increase resistance

Decrease D.L

change structure system



Decrease span

Add Prestressing

with increase resistance

1- increase cross section.

2- Add. RFt

3- Add (Steel) OR (FRP)

4- Replacement of structure element

Repair technique

structure

- Improve strength.
- ~ stiffness.

Non-structure

1- Improve durability.
2- ~ function.
3- ~ appearance.
4- Reduce permeability.
5- Protect Reinforced bars.

---

* المعلومات الواجب معرفتها قبل البدء في عملية الترميم -

* العوامل المؤثرة في اختيار طريقة الترميم.

* Repair techniques :-

1- Crack injection ⟹ Blanketing

- جميع انواع الشروخ راسية ، افقية ، ضيقة ، واسعة
- خاصة الشروخ نتيجة القص (Shear crack)
- اكثر يعيد المقاومة و لا يزيدها.

Grouting

- الشروخ العميقة والواسعة
- يمكن في الحوائط الحاملة (الجيدة)

Routing and sealing

- للشروخ الموجودة في الحوائط و الشروخ الغير متحركة
- لا تصلح في حالة الشروخ الكثيرة.

blanketing

- الطريقة الوحيدة للشروخ الفعالة

Drilling and plugging

- للشروخ الراسية (لإعادة في الـ Retaining walls)

stitching (الخياطة)

- مشهورة في المنشآت الأثرية والمنشآت الحجرية.

Dry back

- اذا كان لدينا بلاطة خرسانية تدق بها تآكل.

Prepacked Aggregate concrete

- للاعمدة والترميم تحت الماء

concrete Jacking

- للاعمدة والكوازين
- تزيد وتعيد المقاومة
- اسهل طريقة للأعمدة سواء كان (ترميم او تدعيم)

Replacement of concrete

- افضل الطرق من حيث اعادة المقاومة

Wrapping of FRP

- ترميم او تدعيم (اعمدة ، كمرات ، بلاطات)

hot crete

طريقة تسخين

External prestressing

- ترميم او تدعيم (اعمدة ، كمرات)

Ain Shams University
Faculty of Engineering
4th Year - Structural Engineering Department

Repair and Strengthening of Structures
هدن ٤٢١ ج ف
2nd Term Exam. (May, 2003)
Time Allowed : 3 hours

Answer 8 Questions Only
(The Exam. Consists of 10 Questions)

Question (1):

a- What are the differences between repair and strengthening of concrete structures?

b- Draw relationships show the effect of each of :
repair – maintenance – protection
on the service life of structures.

Question (2):

For the evaluation of a reinforced concrete flat slab (thickness 25 cm and span 7 m in both ways) the following results were obtained:

1) Three cores of diameter 10 cm and height after capping 12.3 cm were drilled, and then tested in compression. Failure loads were 16 – 14.8 – 14.2 ton respectively. The average 28 days cubic compressive strength = 300 kg/cm^2.

2) Loading test was carried out for the slab and deflections were recorded in four positions. Test results were as follows:

Position		1	2	3	4
Deflection (mm)	After 24 hours of loading	16.6	30.30	20.30	14.90
	After 24 hours of unloading	3.32	2.45	4.47	2.23

a) Discuss the safety of the tested slab according to the requirements of the Egyptian Code for concrete structures.

b) If the tested slab failed to verify the requirements of the Egyptian Code for concrete structures, state the possible ways to make it safe.

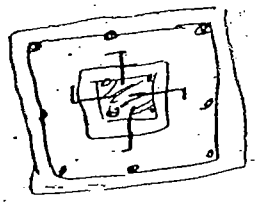
Question (3):

"During the evaluation of a reinforced concrete structure it was concluded that some reinforced concrete columns in the ground floor needs strengthening."

1) state and explain briefly possible methods can be used for the strengthening of this elements (columns).

2) Compare between each of strengthening methods (for ground floor columns) taking the following into consideration:

a) All used materials.
b) Elapsed time to finish work.
c) Durability and protection needed.
d) All over cost.



(7)

Ain Shams University
Faculty of Engineering
4th Year - Structural Engineering Department

Repair and Strengthening of Structures
هدن ٤٢١ ج ف
2nd Term Exam. (May, 2003)
Time Allowed : 3 hours

Question (4):

"FRP materials consist of a large number of continuous, directionalized, non-metalic fibers with advanced characteristics, bundled in a resin matrix."

1- Discuss this statement.
2- State different types and properties of these non-metalic fibers and compare between it and steel.
3- What are the different FRP systems?
4- Given below the mechanical properties for constituent materials of FRP composite:

Material	Modulus of Elasticity (GPa)	Ultimate Tensile Strength (MPa)
Fiber	220	4000
Resin	3	80

If the volume fraction of fibers in FRP equals 70 %, calculate each of the following for a strip with a width of 50 mm and thickness of 1.0 mm:

a) Modulus of elasticity.
b) Ultimate load.
c) Ultimate strain.

Question (5):

1) Define the term "compatibility".
2) Discuss the compatibility of the following repair materials with base concrete?. Which one can be chosen as a suitable repair material for the repair of concrete floors of an industrial meat plant?

Mechanical or Physical Property	Base Concrete	Cementitious Material	Polymer modified Material	Resinous Material
Modulus of Elasticity (G.Pa)	20	25	20	15
Coefficient of Thermal Expansion ($C^{-1} \times 10^{-6}$)	11	10	13	28
Maximum Service Temperature (°C)	200	> 300	200	60
Drying shrinkage (micro-strain)	-----	1500	600	150

Discuss the effect of the use of each of the three repair mortars on the predicted service life of the repaired structure.

(8)

Ain Shams University	Repair & Strengthening of Structures
Faculty of Engineering	(ت ع ٤٢١ ش م)
4th Year - Structural Engineering	2nd Term Exam (May, 2003)
Department	Time Allowed: 3 hours

Question (6):

1. What are the main differences between *crack injection* and *crack grouting* techniques.
2. Differentiate between the stress distribution along the rectangular cross section of a beam repaired *with* and *without* unloading process.
3. Compare between the most used resins for crack injection in view of *strength, hardening time and applications.*

Question (7):

1. Give the differences between *concrete replacement* and *jacketing* techniques.
2. State down the two types of *injection points* and the applicability of each type.
3. Compare between *Wet* proccess and *Dry* proccess methods used in shotcrete repair techniques.

Question (8):

Using neat sketches *only*, explain the following:

1. Examination of the *activity* of structural cracks in concrete elements
2. *Direction* of crack injection along the line of crack.
3. Shape of joint after *blanketing of active cracks* with and without bond breaker.
4. Different schemes of strengthening isolated *RC footing*.
5. Both of *rooting* and *sealing* of cracks.

Question (9):

The outer surface of the walls of the sedimentation tank in a water treatment plant was partially affected by water which led to efflorescence and spalling what gives indication of internal corrosion of the reinforcement. Figure 1 illustrates the condition of the tank. Suggest a remedy procedure for the tank.

Question (10):

A ground floor column in a residential building in the same project was affected by the deficiency in construction workmanship that manifests honycombing of the lower portion of the column. The field tests showed that the honycombing infiltrated through the entire cross section of the column. Figure 2 illustrates the condition of the column. Suggest a remedy procedure for the column.

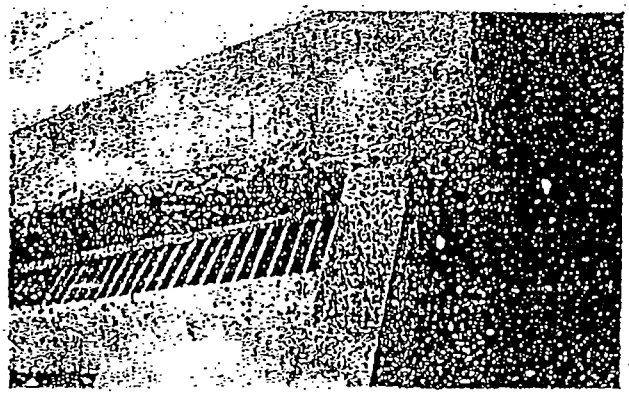


figure 1

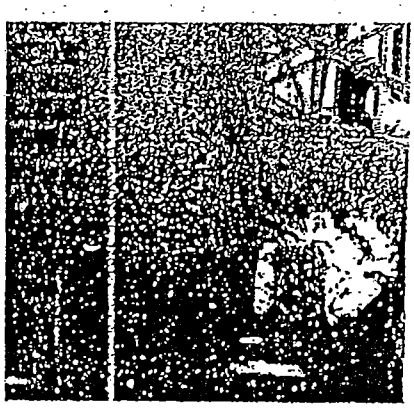


figure 2

GOOD LUCK

May 2003

Question (I) :

a-

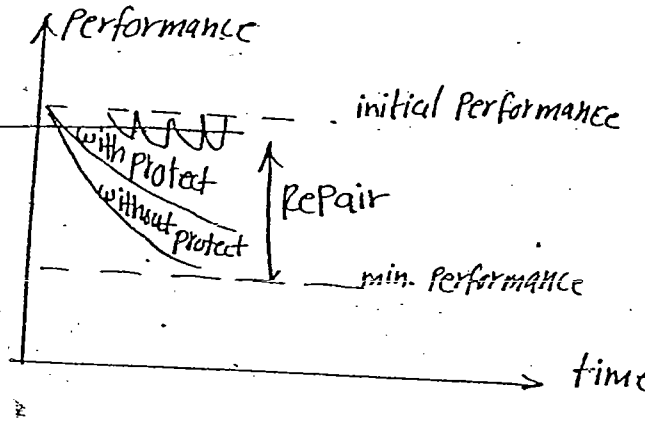
* الترميم : Repair ← اعادة المقاومة .

يتم الترميم فى حالة حدوث عيوب بالعناصر الإنشائية تؤدى الى تقليل مقاومة هذه العناصر للاجهادات التى يتعرض لها المنشأ ، فى هذه الحالة يجب عمل العلاج المناسب لإعادة العناصر الانشائية الى حالتها الاصلية .

* التدعيم : strengthening ← زيادة المقاومة .

يتم لزيادة كفاءة العناصر الإنشائية بسبب تعرضها لأحمال أكبر من التى تتحملها هذه العناصر بأمان مثل (احمال اضافية / احمال زلازل / انشاء دور اضافى ...) وليس بسبب عيوب ظاهرة بهذه العناصر

b-



initial Performance ← min اعادة

* يتم عمل الـ repair لزيادة ادائية المنشأ من

* ~ ~ ~ الصيانة maintenance لتقليل من تكلفة الترميم .

* الحماية protection تطيل من عمر المنشأ .

Question (2):

أ)

* For core test

لكى تكون الخرسانة متطابقة مع الكود المصرى يجب :-

1- $f_{av} \geq 0.75\ F_{cu}$ و $f_{min} \geq 0.65\ F_{cu}$

وذلك لـ ٣ عينات على الأقل

$$f = f_{cy} * C.F = \frac{P_{max}}{area} * \frac{F}{1.5 + d/h} \quad (kg/cm^2)$$

$P_{max_1} = 16\ t$ ، $P_{max_2} = 14.8\ t$ ، $P_{max_3} = 14.2\ t$

$$area\ for\ all = \frac{\pi d^2}{4} = \frac{\pi * (10)^2}{4} = 78.54\ cm^2$$

$$C.F\ For\ all = \frac{23}{1.5 + 10/12.3} = 0.9944$$

(23 بالضبط)

$$\therefore f_1 = \frac{16 * 10^3}{78.54} * 0.9944 = 202.57\ kg/cm^2$$

$$f_2 = \frac{14.8 * 10^3}{78.54} * 0.9944 = 187.38\ kg/cm^2$$

$$f_3 = \frac{14.2 * 10^3}{78.54} * 0.9944 = 179.78\ kg/cm^2$$

$$\therefore f_{av} = \frac{202.57 + 187.38 + 179.78}{3} = 189.9 \not\geq 0.75\ F_{cu}$$

$(225\ kg/cm^2)$

$\therefore$ unsafe

$f_{min} = 179.78 \not\geq 0.65\ F_{cu}$

(195) $\therefore$ usafe

$\therefore$ هذا الاختبار غير مقبول

For loading test

لكي تكون الخرسانة متطابقة مع الكود المصري يجب :-

1- δ_{max} (mm) $\leq \dfrac{L_t^2}{20000\,t}$

L_t → البعد الأصغر في البلاطة (mm)

t → سمك البلاطة (mm)

δ_{max} → Deflection after 24hr of loading

2- IF $\delta_{max} > \dfrac{L_t^2}{20000\,t}$

∴ δ_{res} (mm) $< 0.25\,\delta_{max}$

δ_{res} → Deflection after 24h of unloading

For this proplem ⇒ $\dfrac{L_t^2}{20000\,t} = \dfrac{(7000)^2}{20000\,(250)} = 9.8$ mm

Position (1)	Position (2)	Position (3)	Position (4)
$\delta_{max} = 16.6$ mm	$\delta_{max} = 30.30$ mm	$\delta_{max} = 20.30$ mm	$\delta_{max} = 14.90$
$\delta_{max} > \dfrac{L_t^2}{20000\,t}$ (9.8mm)	1- $\delta_{max} > 9.8$	1- $\delta_{max} > 9.8$	1- $\delta_{max} > 9.8$
$\delta_{res} = 3.32$ mm	2- $\delta_{res}^{*} = 2.4$ mm	2- $\delta_{res} = 4.47$ mm	2- $\delta_{res} = 2.23$
δ_{res} (3.32) $< 0.25\,\delta_{max}$ (4.15 mm)	δ_{res} (2.4) $< 0.25\,\delta_{max}$ (7.575)	δ_{res} (4.47) $< 0.25\,\delta_{m}$	$\delta_{res} < 0.25\,\delta_{max}$
∴ safe	∴ safe	∴ safe	∴ safe

د)

١- يمكن تكسير البلاطة بالكامل واعادة صبها من جديد .

٢- يمكن تركيب شبكة حديد سفلية ويتم صب الخرسانة جاكيتة الـ ot crete

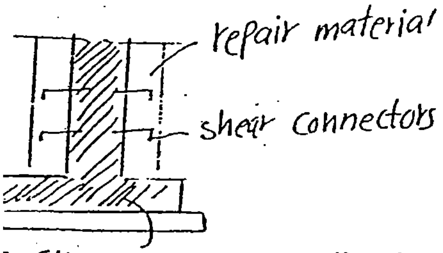
٣- يمكن اضافة بعض الكمرات لتحويل نظام البلاطات من Flat الى soild slab

Question (5)

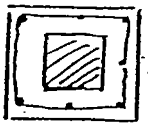
there are Two methods to strength the Column :-

a) Increase Cross section.	b) Add bonded materials	
Concrete Jacking	using steel	using FRP

a) Concrete Jacking



- يراعى ان تكون الخرسانة الجديدة :
- لها محتوى اسمنت عالى
(cement content ≮ 400 kg/m³)



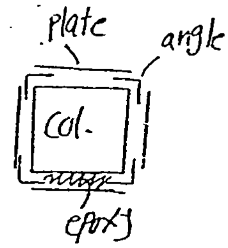
- تستخدم shear connectors لربط الخرسانة القديمة بالجديدة / ايضا استخدام دهانات لزيادة التماسك
- يجب ان تكون الخرسانة لها Quality control عالية

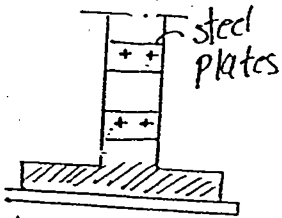
اقلهم من حيث سرعة التنفيذ

- الاهتمام بالخرسانة الجديدة من حيث زيادة الاسمنت والجودة
- عمل الصلبات اللازمة لازالة الحمل عن العمود حيث زيادة العمود .

اقلهم من حيث الثمن

b) Using steel





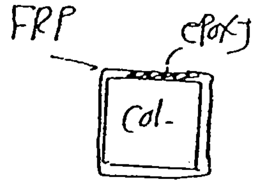
يتم وضع steel plat على العمود

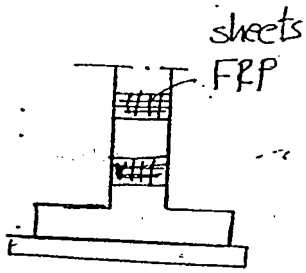
اقل فى السرعة من الـ FRP

- حماية ضد الصدأ

اعلى من الخرسانة واقل من الـ FRP

b) Using FRP





يتم تحزيم العمود بـ GFRP

المزايا :
سهولة التنفيذ وسرعة التنفيذ

- يجب عمل حماية ضد سوء الاستخدام
- ~ ~ ضد درجة الحرارة العالية

اعلاهم فى الثمن

Question (4) :

1- الـ FRP هو عبارة عن Fiber مثل الـ Carbon, glass يتم خلط أى منهم مع مواد إيبوكسية محايد عدى (حفظ الـ Fiber بخواص جيدة مع الوقت / تجعل الـ Fiber تتحمل الأحمال كوحدة واحدة / تزيد التماسك بين الـ Fiber والخرسانة] مما ينتج لنا FRP يكون لها خواص أعلى من الحديد من حيث [مقاومة الشد > سهولة التنفيذ > سرعة التنفيذ

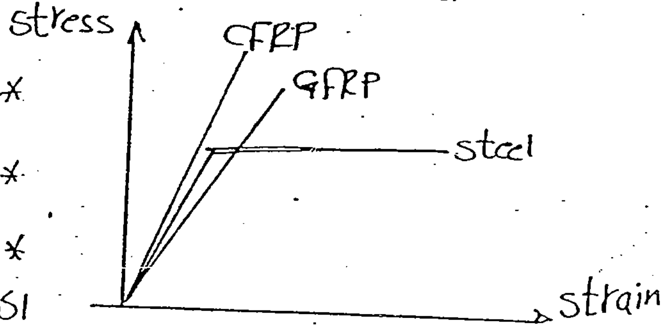
2- Types of FRP

1- CFRP

2- GFRP

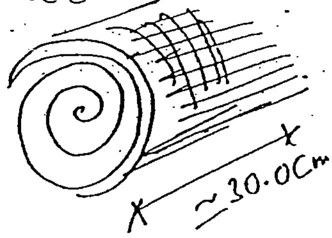
3- Aramaid → له خواص خاصة وغير شائع فى مصر.

* الـ CFRP معاير المرونة له أكبر من الـ steel
* الـ GFRP ~ ~ ~ أقل من الـ steel
* الـ CFRP له مقاومة شد عالية تصل إلى 10 أمثال الحديد



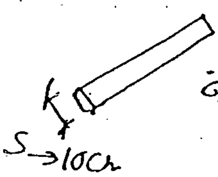
← الانهيار فى الـ FRP يكون فجائى وذلك لعدم وجود Yield مثل الـ

sheets

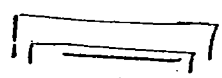


مشكلتها اللاصق على سطح الخرسانة وضمان أن الـ Fiber مشدودة وعدلة.

laminates

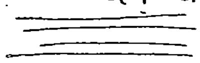


شريحة يتم لصقها على بطنية الكمرة أو على البلاطة



كما يتم تقسيم الـ FRP إلى

uni direction



Bi-direction

-4-

a) $E_{composite\ FRP} = E_{Fiber} * V_{Fiber} + E_{material} * V_{material}$

$\therefore E_{composite\ FRP} = 220 * 0.7 + 3 * (1-0.7)$

Modulus of elasticity $= 154.9$ GPa

---

b) Ultimate Tensile strength (T) $= T_{Fiber} * V_{Fiber} + T_{mat} * V_{mat}$
composite FRP

$= 4000 * 0.7 + 80 * (1-0.7)$

$= 2824$ MPa

$\therefore$ strength $= \frac{Force}{area} \longrightarrow \therefore$ ultimate load $=$ strength $*$ area

$= 2824 * 10^6 * \frac{50}{1000} * \frac{1}{1000} = 141200$ N

MPa $\rightarrow N/m^2$

) Ultimate strain

$\therefore E = \frac{stress}{strain}$

$\therefore strain = \frac{stress}{E} = \frac{2824\ (MPa) * 10^6}{154.9\ (GPa) * 10^9}$

$= 0.01823$

Question (5):

1-

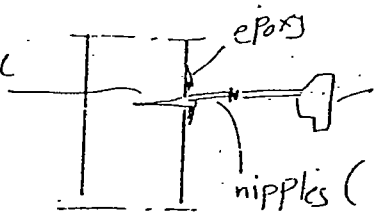
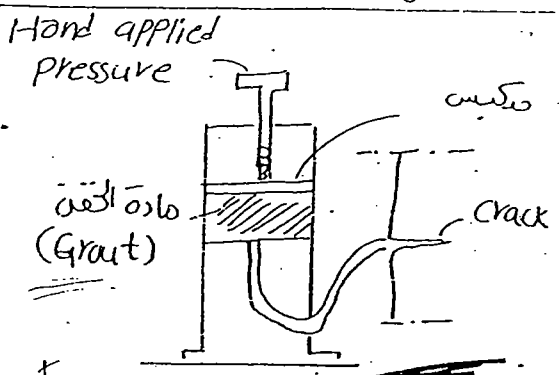
(Compatibility) ـ هو وجود توافق وتجانس بين خواص مادة الترميم والخرسانة القديمة من حيث (الانكماش ومعامل التمدد الحراري والزحف ومعاير الـ
ونسبة بواسون)

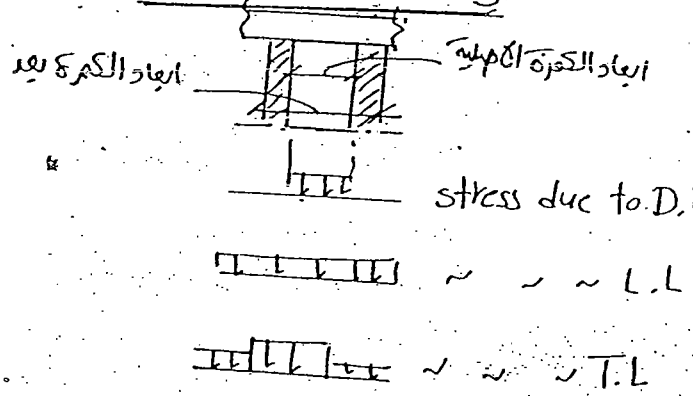
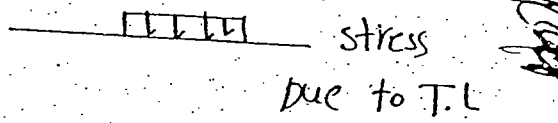
حتى لا تتولد اجهادات بينهما تسبب انفصال المادتين مما يؤدي الى فشل عملية الترميم

Cementitious Material	Polymer modified material	Resinous material
$E_R > E_C$ تتولد بين السطحين قوى قص تؤدي الى الانفصال	$E_R \simeq E_C$ انسب مادة في الترميم من حيث معاير المرونة	$E_R < E_C$ ∴ Non-structure repair وتتولد اجهادات قص ايضا
$\alpha_R \simeq \alpha_C$ انسب مادة من حيث معامل التمدد الحراري	$\alpha_R > \alpha_C$ قد تتولد اجهادات قص	$\alpha_R >> \alpha_C$ ستتولد اجهادات قص تؤدي الى الانفصال.
غير مفضل من حيث الكفاءة لدرجة الحرارة	افضل مادة من حيث الكفاءة لدرجة الحرارة	غير مفضل
غير مقبولة (مرفوضة) من حيث الانكماش 7/500	قد تكون مقبولة ولكن غير مفضلة (حيث يفضل ان يكون الانكماش اقل ما يمكن)	ـ افضلهم من حيث الانكماش ـ الاقل في الانكماش افضل

Question (6):

1.

Crack Injection	Crack Grouting
	
* مادة الحقن ← مادة ايبوكسية ذات انسيابية عالية * الضغط الذى تؤثر به أقل. It Repair deep narrow cracks * فى الكمرات الشروخ الضيقة والعميقة	* مادة الحقن ← Grout * الضغط الذى تؤثر به اقل. For Repair very deep, not straight and wide cracks. الشروخ العميقة والغير مستقيمة والعريضة

without unloading	with unloading
	

1- (epoxy) ← افضل المواد (يكون فى شكل سائل ويتحول بعد ذلك الى متصلب وهذه المرحلة تسمى (polymerization)

2- (Polyester) ← اقل درجة من الايبوكسى

3- خليط من الايبوكسى والبوليستر (يفضل فى حالة الشروخ الموجودة فى المنشآت الحائية)

Question (7):

1-

Concrete Replacement	قميص Jacking
- انسب طرق ترميم الاعمدة او الكمرات او البلاطات	- انسب طرق ترميم او تدعيم الاعمدة
- لا تزيد مقاومة المنشأ ولكن تعيد المقاومة.	- تزيد مقاومة المنشأ.
- لا تسبب تغير الشكل المعماري للمنشأ	- تسبب تغير الشكل المعماري للمنشأ
- أقل في التكلفة.	- أعلى في التكلفة
* يتم تكسير الغطاء الخرساني حتى صنفرة الحديد الحديد ثم صب الخرسانة بالغطاء الخرساني.	* يتم زنبرة سطح الخرسانة القديمة ثم يتم صب خرسانة الجديدة بجوارها.

2-

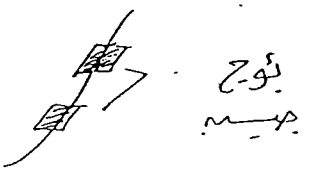
* في حالة الشروخ الافقية الاسطح الافقية يتم توسيع الشرخ (حوالي ٥مم) وينظف جيداً.
ثم يتم صب مادة الحقن في الشروخ مباشرة حتى تمتلئ تماماً

* في حالة الشروخ الرأسية يتم توسيع الشرخ (حوالي ٥مم) ثم يقفل سطح الشرخ بواسطة مونة سريعة الشك مع وضع مواسير معدنية ذات صمامات مانع للرجوع (nipples) ويتم الحقن باستخدام مسدس الحقن.

Dry Process	Wet Process
* يتم خلط الرمل والاسمنت والزلط ثم وضعهم في الجهاز ثم يتم اضافة الماء الى الخليط (الكمية صغيرة حتى لا) اصطكاك داخل مواسير الجهاز اثناء القذف من الجهاز	* يتم خلط الخرسانة والماء ثم يتم ضخهم بعد ذلك في الماكينة
* المميزات :-	* المميزات :-
more consistent	1- less rebound
Rebound is generally (20-30%)	2- better control of W/C
silica fume (5-10%) may be ed to reduce the rebound	

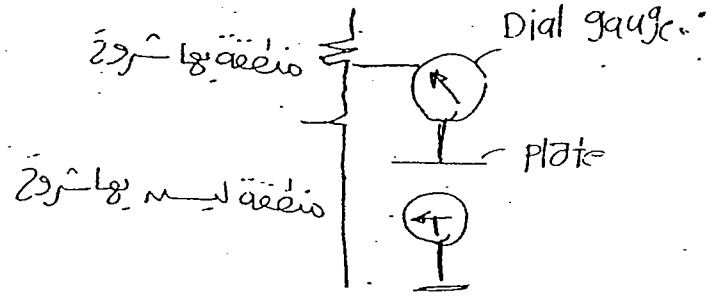
QUESTION (5):

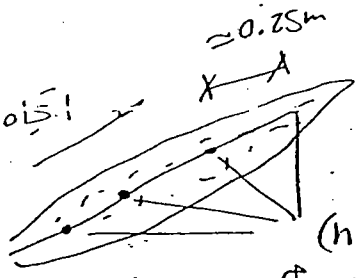
1-



بوج
عيب

فى حالة ظهور شروخ فى البوج
يكون هذا الشرخ فعال





(nipples)

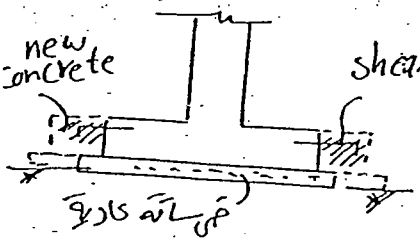
مواسير معدنية ذات صمام
مانع للترجيع

* يكون الحقن من اسفل الى أعلى
بالترتيب حيث لان تقوم بتزح
جميع الحقن من النقطة
التى تحقن منها الا بعد خروج
مادة الحقن من النقطة التى
تليها وبالتالى نضمن ان مادة الحقن قد ملأت جميع الفراغات فى الخرسانة.

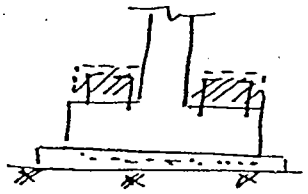
bond breaker

عدم وجود الـ bond breaker

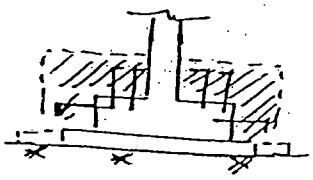
يسبب شروخ فى المادة الخطأ التى تتم وضعها مكان الشرخ



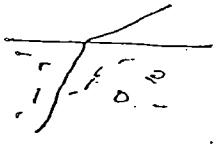
زيادة حجم القاعدة



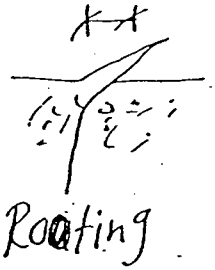
زيادة سمك القاعدة



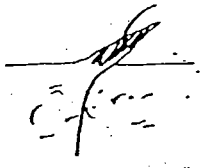
زيادة الوزن والسمك



Crack



Roating



Scaling

مادة
إيبوكسية
(ذات انكماش
منخفض)

Question (9)

* Replacement of Concrete structure *

shot crete

* يتم ازالة الغطاء الخرساني
- ثم يتم صنفرة الحديد من الصدأ بالرمالة
- ~ ~ دهان الحديد بمادة مانعة للصدأ
- ~ ~ صب الغطاء بماكينة الـ shot crete

ولكن قبل كل ذلك يجب الاهتمام بالعزل المائي للخزان حتى لا يتكرر ذلك حيث أن اهم شئ في عملية الترميم هو معالجة او انهاء السبب في المشكلة قبل البدء في عملية الترميم.

Question (10)

* Concret Jacking *

= يتم عمل قميص خرسانة حول العمود [انسب طريقة للأساسات سواء كان ترميم او تدعيم]

= او من الممكن صب خرسانة مكان هذا التقشير باستخدام ماكينة الـ shot crete

والسبب في هذا التقشير هو عدم استخدام هزاز ميكانيكي اثناء الصب و عدم الاهتمام اثناء التنفيذ (الصب) بدمك الخرسانة.

4th Year - Structural Engineering Department | 2nd Term Final Exam (June 2002) | Time Allowed : 3 hours

Attempt all Questions
(the Exam Consists of 4 Questions in 3 Pages)

Question (1) [25 %]:

A reinforced concrete building consistes of 3 floors was examined due to required increase in live loads (from 300 kg/m^2 to 450 kg/m^2)

① Outline the procedure of evaluation of this structure and state some of the possible deffects, cracks which may appear during the visual inspection of the structure.

② State three non-destructive tests carried out for the evaluation of the structure elements (columns – beams – slabs) showing possible results in each test.

③ For the evaluation of a reinforced concrete flat slab of thickness 18 cm and spacing between columns 5 m in both directions in this building the following results were obtained:

a- Three cores of diameter 10 cm and height after capping 12.3 cm were drilled, and then tested in compression. Failure loads were 16 – 14.8 – 14.2 ton respectively. The average required 28 days cubic compressive strength = 250 kg/cm^2.

b- Loading test was carried out for the slab (taking into consideration new live load value) and deflections were recorded in four positions. Test results were as follow:

Position		1	2	3	4
Deflection (mm)	After 24 hours of loading	5.10	10.52	6.25	4.33
	After 24 hours of unloading	1.52	3.6	2.12	0.82

Discuss the safety of the tested slab according to the requirements of the Egyptian Code for design and construction of reinforced concrete structures (No. 203-2001). If the slab is unsafe with new live load value; give your proposed solutions to make it saf...

④ After evaluation it was conciuded that some columns must be strengthened, discuss the possible methods and materials can be used for strengthening. Give advantages and disadvantages of these methods; taking into consideration:
Price of 1 m2 of building – Cost of strengthening materials – Strengthening time schedule – Base concrete quality – Structure serviceability.

Question (2) [25 %]:

① State main factors affect the bond strength between repair materials and substrate concrete. Discuss possible methods can be used to increase this bond.

2- Put sign (✓) or (×) beside each of the following statements. If the statement is wrong; rewrite it in the best form:

(a) For a reinforced concrete slab: there is no difference between crack paterns due to steel reinforcement corrosion and structural overloading.

(b) Repair can be defined as to replace or correct deteriorated, damaged, or faulty materials, components, or elements of a structure.

(c) Increasing the cross-section of concrete columns is more significant strengthening method than increasing the cross section of a concrete beam.

d- In the case of non-structural repair, loaded in compression, the repair material must possess very low creep potential.

c- When selecting a repair material, designer should ensure that both substrate concrete and repair materials possess similar elastic moduli.

f- Adding micro polypropylene fibers to repair mortars reduces tendency to cracking.

"The term Compatibility has become very popular in the field of concrete repair" Discuss this statement?. To select a suitable repair material for a reinforced concrete chimney, substrate concrete and different types of repair materials (A, B & C) were investigated. The properties of all tested materials are as follow:

Property	Substrate	Material A	Material B	Material C
Modulus of elasticity (G.Pa)	20	15	20	23
Poisson's ratio	0.18	0.30	0.22	0.2
Coefficient of thermal expansion ($1/°C) \times 10^{-6}$	11	28	12	11
Drying shrinkage (micro-strain)	---	150	600	1350
Maximum service temperature (°C)	200	60	200	> 300

a- Chose the suitable repair material. Give your reasons.
b- Discuss the effect of the use of each one of the three repair materials on the predicted service life of the repaired structure.

Question (3) [25 %]:

1. Give brief answers for the following questions
   a. What are the objectives of each of *Structural* and *Non-Structural* repair techniques?
   b. Compare between *Wet* proccess and *Dry* proccess methods used in shotcrete repair techniques.
   c. What are the methods, commonly used, for bonding of external steel plates to the bottom of RC beams.
   d. What are the factors affecting the choice of crack injection pressure in concrete.
   e. State down the two types of injection points and the applicability of each type.

2. Choose the most suitable repair/strengthening technique for each of the following defects in concrete elements:
   a. Wide and very deep straight cracks.
   b. Deep narrow cracks.
   c. Easy access of corrosive materials.
   d. Insufficient stiffness.
   e. Limited number of very narrow cracks.

3. Using neat sketches *only*, explain the following:
   a. Examination of the *activity* of structural cracks in concrete structures.
   b. *Drilling and plugging* of RC walls.
   c. Both of *Rooting* and *Sealing* of cracks.
   d. Repair of existing bending cracks using external bonded *steel plates*.
   e. External *prestressing* of RC slab to control existing bending cracks.

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Question (4) [25 %]:

1. "Releasing the applied live loads on concrete elements before commencing the repair work is a must for different reasons".
   a. What are the advantages of unloading of RC elements during repair.
   b. Explain with schematic diagrams the different techniques of RC columns unloading.
   c. Draw sketches for unloading methods of RC wall and RC footing.
2. Give some of the general recommendations to be included in the final report for the repair of existing reinforced concrete building.
3. For each of the following strengthening details shown in *fig. 1 to fig. 4*
   a. explain the possible problems for which the remedy was carried out.
   b. State the precautions for surface preparation and materials used for the strengthening techniques shown in *fig. 3 and fig. 4*.

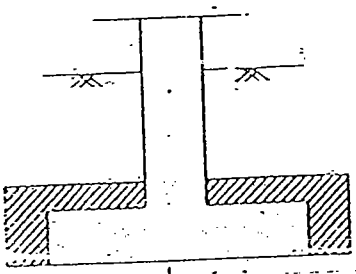


Fig. (1)

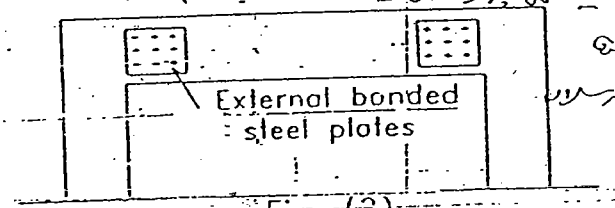


Fig. (2)

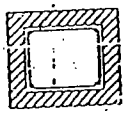


Fig. (3)

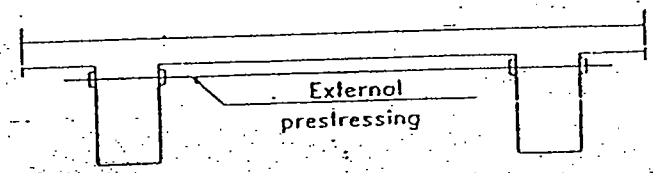
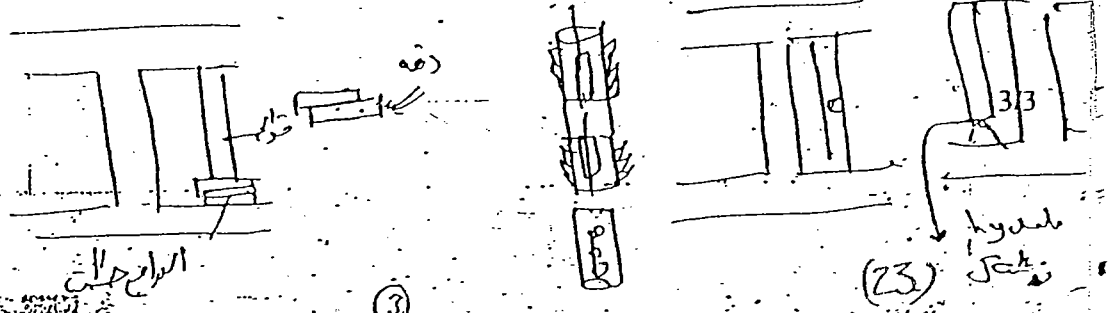


Fig. (4)

Existing R.C New R.C

GOOD LUCK.

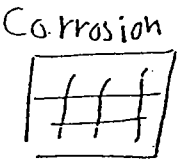


June 2002

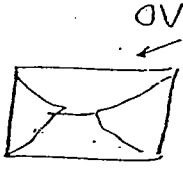
Question (2):

2-)

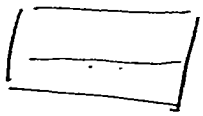
a- (X)



يكون الشرخ في اتجاه حديد التسليح.



Two way Slab



one way slab

b- (✓)

حيث ان الترميم هو عملية اعادة مقاومة للاجزاء التالفة التي فقدت مقاومتها للاحمال

c- (✓)

d- (X) ---- very high Creep Potential.

-(✓) For $E_{Repair} = E_{concret}$

لا تتولد اجهادات قص فلا يحدث انفصال بين المادتين مهما زاد حمل التوافق بين المادتين بحيث يعملان معاً كوحدة واحدة في مقاومة الاحمال

-(✓)

Question (4):

a-) Replacement of concrete cover

يتم ازالة الغطاء الخرساني ثم يتم ازالة هذا الحديد او صغرته مع وضع حديد اضافي اسفل الكمرة حيث ان كمية هذا الحديد كبيرة لذلك لا يحقق الاعتماد على هذا الحديد في مقاومة احمال الشد ثم يتم بعد ذلك صب الغطاء الخرساني باستخدام ماكينة القاذف الخرساني ((Shot crete))

---

b) Concrete Jacking

اسم حل للاعمدة سواء كان ترميم او تدعيم

Jacking
Jacking
Jacking

- يحقق تكسير هذه البلاطة تماماً واعادة صبها من جديد (افضل حل)
- او يتم تكسير الغطاء الخرساني ويتم اضافة شبكة حديد عليها (7ϕ12/m)
يتم تزريعها في الكمرات المحيطة بالبلاطة ثم يتم صب الخرسانة من فوق لزيادة سمك البلاطة اي > 14cm من اسفل لاعادة الغطاء الخرساني.

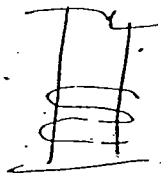
---

d) ١- يحقق اضافة steel plates في المنطقة التي ليس بها كانات لمقاومة القص

٢- " " لصق CFRP او GFRP " "

٣- يحقق عمل تدعيم خرساني لهذه المنطقة فقط (غير مفضل لتغيير الشكل المعماري)

٤- اضافة Prestressing wires :



Ain Shams University
Faculty of Engineering

4th Year - Structural Engineering
Department

Repair & Strengthening of Concrete Structures
(هدن ٤٠٤ ج ف)
2nd Term Final Exam (June 2001)
Time Allowed : 3 hours

Attempt all Questions
(The Exam. Consists of 4 Questions in 3 Pages)

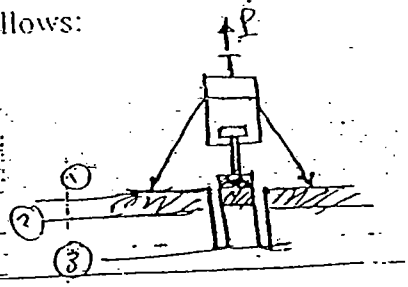
Question (1): (25 %)

1- Using net sketches, explain each of the following:
(a) A rehabilitation repair in which corroded reinforcement together with damaged concrete were replaced.
(b) Strengthening of a concrete beam by adding reinforced bars in the tension side.
(c) Careful visual inspection of fire damaged concrete structure can be used to determine the extent of damage.
(d) Effects of drying shrinkage of repair materials on the serviceability of repair works.

2- Give some applications (using net sketches) for the use of the following materials in repair and strengthening works:
(a) Fibre reinforced plastics.
(b) Bonding coats.
(c) Pre-stressing strands or wires.
(d) Epoxy Zinc.
(e) Shear connectors.

3- Core pull-off tests were carried out to estimate the bond strength between repair mortar and substrate concrete. four steel targets of diameter 50 mm were glued to repair surface using a suitable adhesive. Test reaults were as follows:

Test No.	Failure load (kg)	Mode of failure
1	550	Substrate failure
2	500	Interface failure
3	590	Repair failure
4	560	Interface failure



(a) Estimate each of the tensile strength of substrate concrete and the average bond strength between repair mortar and substrate concrete.
(b) Using net sketches, show the mode of failure for each test.

Question (2): (25 %)

(1) "The term compatibility has become very popular in the field of concrete repair" Dicuss this statement?

(2) To select a suitable repair material for each of the following works (shown in figures), substrate concrete and different types of repair materials (A: B & C) were investigated. The properties of all tested materials are as follows:

(26)

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Faculty of Engineering
4th Year - Structural Engineering Department

Repair & Strengthening of Concrete Structures
(هدن 421 ج ف)
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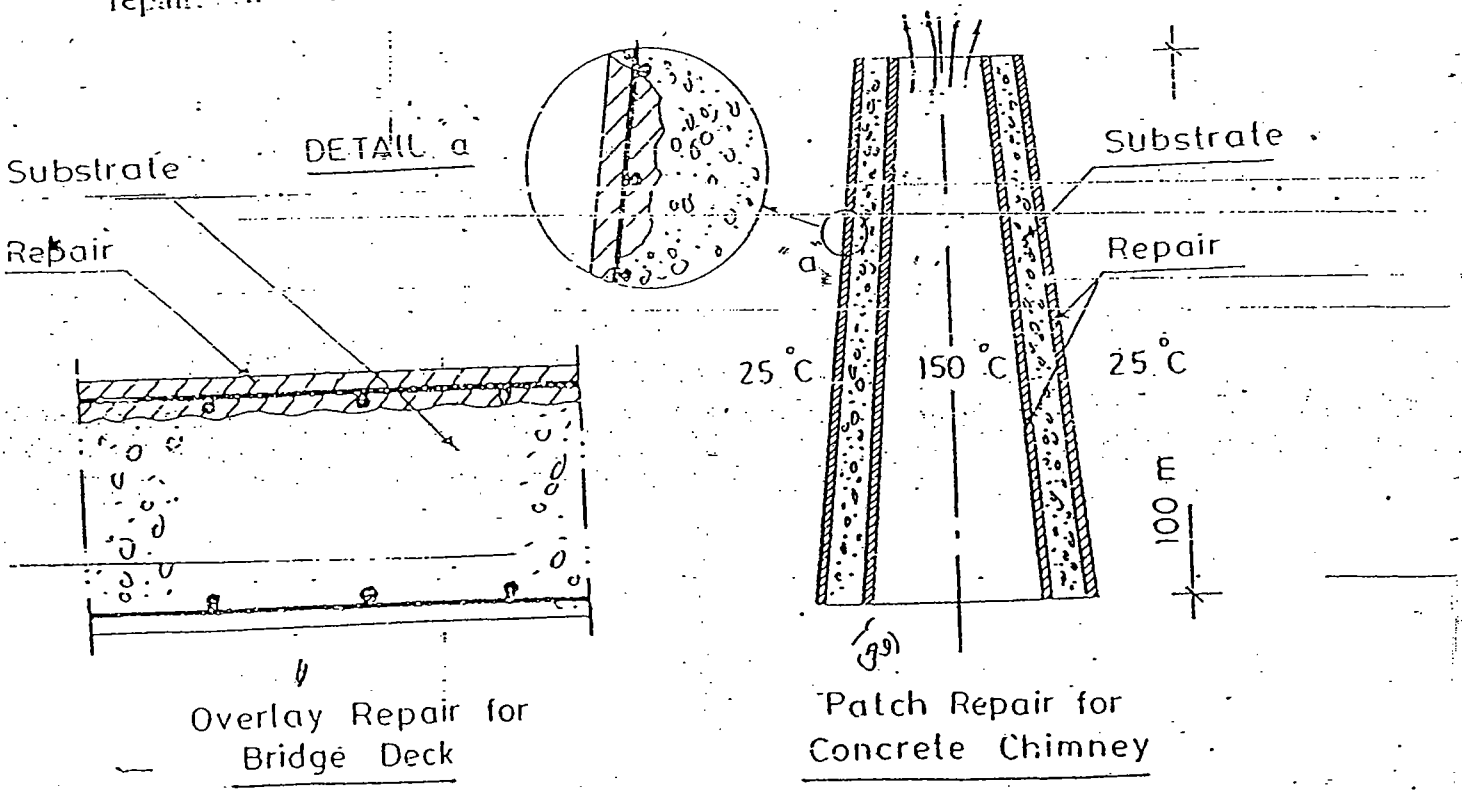
Property	Substrate	Material A	Material B	Material C
Modulus of elasticity (G.Pa)	20	15	20	23
Poisson's ratio	0.18	0.30	0.22	0.2
Coefficient of thermal expansion $(1/°C) \times 10^{-6}$	11	28	12	11
Drying shrinkage (micro-strain)	---	150	600	1350
Maximum srevice temperature (°C)	200	60	200	> 300

i- Chose the suitable repair material for each case. Give your reasons.
ii- Suggest the suitable repair procedure and used techniques for each case.
iii- Add to the given drawings any other materials you need to achieve lasting repair.



Question (3): (25 %)

1- Put sign (✓) or (x) beside each of the following statements. If the statement is wrong; put it in the right form:

(a)- In the majority of concrete structures, cracks result in structural failure. ✗ but they can result in definite loss of

b- Strengthening can be defined as to replace or correct deteriorated, damaged, or faulty materials, components, or elements of a structure. ✗ performance of the Structure

Repair

P.T.O. (27)

Ain Shams University
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c- Increasing the cross section of concrete beams is more significant strengthening method than increasing the cross section of a concrete column. ✗
d- Placing additional reinforcement in the tension zone of a reinforced concrete beam (protected by an additional concrete cover or by shotcrete) is a very effective strengthening method. ✓
e- In the case of structural repair, loaded in compression, the repair material must possess very low creep potential. ✗
f- When selecting a repair material, designer should ensure that both substrate concrete and repair materials possess similar elastic moduli. ✓
g- Cementitious based materials has similar coefficient of thermal expansion. ✓
h- Adding silica fume to repair mortar reduces rebound during shotcreting. ✓

2-(a) Differentiate between each of the following terms:
Spalling – Scaling – Crazing
(b) Note down the desirable qualities for epoxy injection resins.
(c) State down briefly the practical steps used in executing the grouting of cracks.

① low viscosity.
② low shrinkage.
③ Ability to bond to Deep Cracks.
④ Toughness rather than strength.
⑤ Injection as much as possible.

Question (4): (25 %)

For each of the following cases and using net sketches, state the most suitable repair strengthening techniques – materials needed – main properties of each material:

(a) A simply supported concrete beam in which 60 % of the area of main reinforcement lost due to corrosion.

(b) A concrete column in the ground floor of a building for which structural calculations show that the actual compressive stress on column = 125 kg/cm^2. Evaluation of the column shows that the grade of concrete is 250.

(c) A reinforced concrete slab shows high values of deflection, besides hair distributed mesh cracks in the tension side. Evaluation of slab shows that the actual slab thickness is 9 cm and main reinforcement is 5 o 10 /m in both directions. Structural drawings show that slab thickness is 14 cm and main reinforcement is 7 o 12 / m in both directions.

(d) A concrete column of clear height 4 m, inspection of column reinforcement shows that the last 2 m of column is free from stirrups (stirrups dropped down during casting).

GOOD LUCK.

(28)

June 2001

Question (1)

3- a) Tensile strength of substrate concrete From Test NO. 1

$$f_t = \frac{P_{max}}{area} \quad \& \quad area = \frac{\pi d^2}{4} = \frac{\pi * (5)^2}{4} = 19.63\ cm^2$$

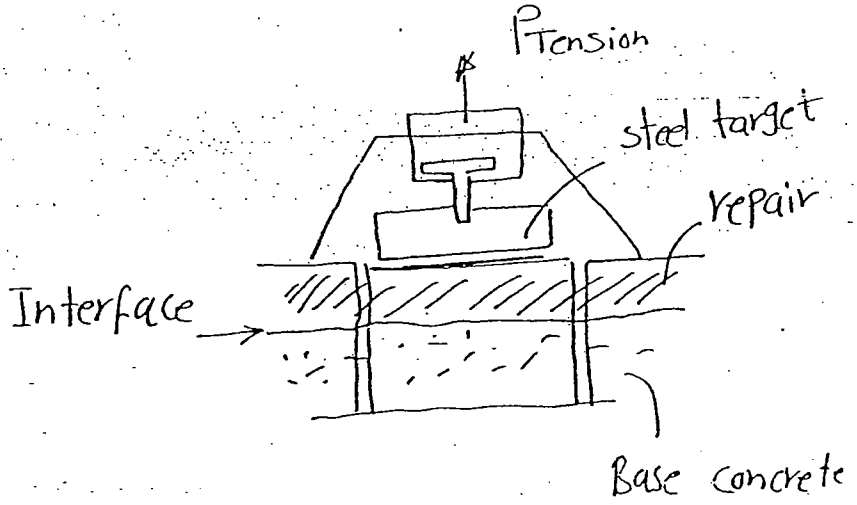
$$\therefore f_t = \frac{550}{19.63} = 28.01\ kg/cm^2$$

Average bond strength between repair mortar and substrate concrete From Test NO. 2 & Test NO. 4

$$f_{t\ From\ test\ 2} = \frac{500}{19.63} = 25.46\ kg/cm^2 \quad \& \quad f_{t\ From\ test\ 4} = \frac{560}{19.63} = 28.52\ kg/cm^2$$

$$\therefore \text{average bond strength of tall angles} = \frac{25.46 + 28.52}{2} = 26.99\ kg/cm^2$$

b)



9- During the evaluation of a concrete structure the quality of concrete footing, ground beams, and column were checked by Schmidt hammer, Ultra-sonic pulse velocity, and Core tests. Test results are as follows:

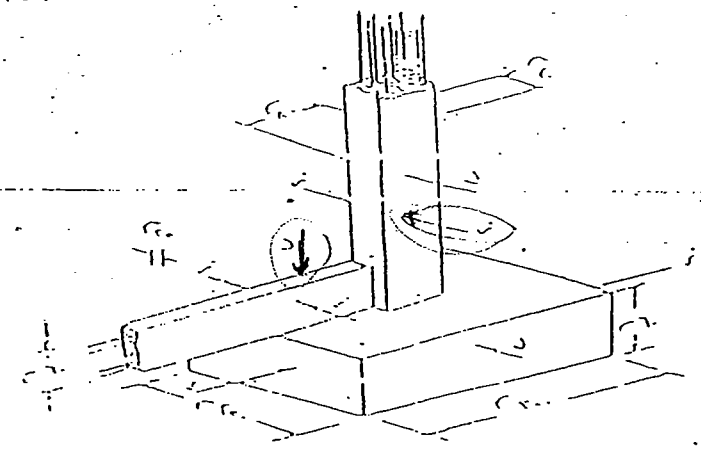
Concrete Element			Footing	Ground beam	Column
Test Results	Schmidt Hammer	Rebound No.	36 - 28 - 27 – 29 25 – 24 – 26 – 32 34 – 24 – 27 - 28	27 – 29 – 31 – 28 32 – 33 – 30 – 30 24 – 31 – 40 - 31	35 – 37 – 32 – 38 37 – 36 – 37 – 38 34 – 32 – 34
	Ultra-sonic	Transit Time (μsec)	1330 – 1326 1336 – 1334 1329 - 1331	69 – 67 – 66 71	83 – 80 – 85 81 – 82 – 79 84
		Correction Factor	0.948	0.98	0.88
	Core Test	Direction of Drilling	Vertical	Horizontal	Horizontal
		Diameter of Specimen (mm)	10.0	7.0	7.0
		Height of Specimen (mm)	15.1	10.2	8.5
		Height after Capping (mm)	16.2	11.0	9.4
		Weight (gm)	2635	895	740
		Failure Load (ton)	9.4	8.5	9.1

Direction and placing of tests are shown in figure (1)

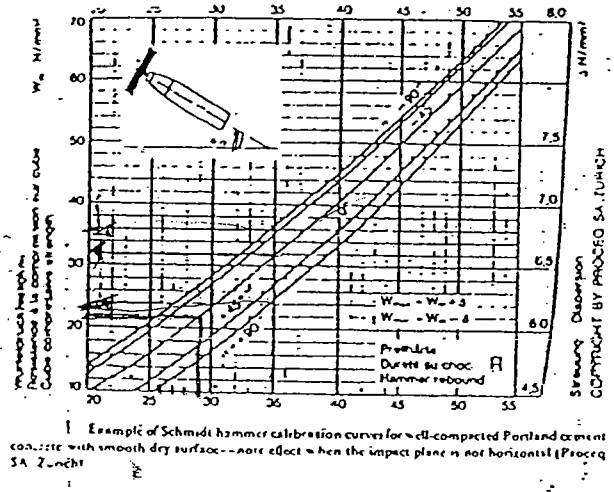
a- Differentiate between the advantages and disadvantages of the use of the last techniques for the evaluation of concrete structures.

b- B- Calculate the compressive strength of all concrete elements by the use of test results of each technique (figures 2, and 3 may be used).

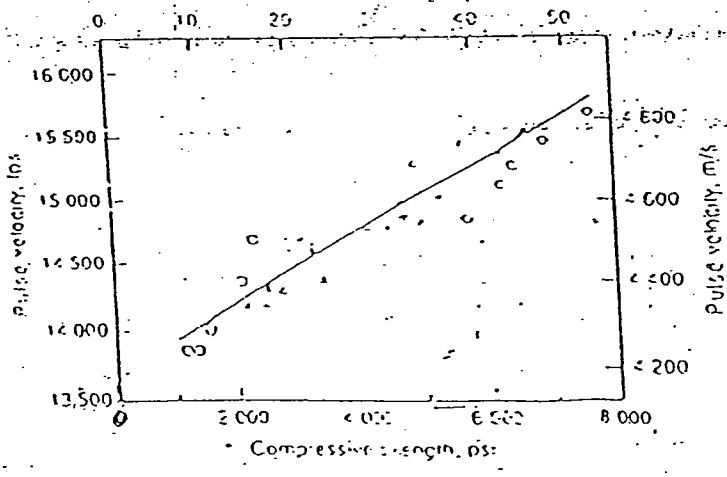
c- Discuss the causes of difference in results.



شكل (١) : مواضع اجتياز مطرقة شميدت (د) و الموجات فوق الصوتية (و)



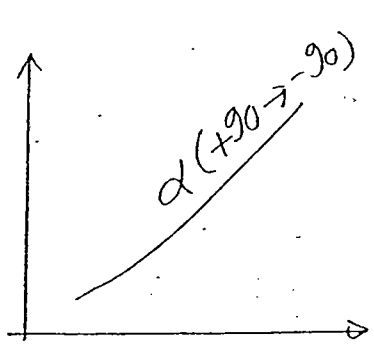
شكل (٢) : العلاقة بين وقت انتشاء و مقاومة الضغط للخرسانة

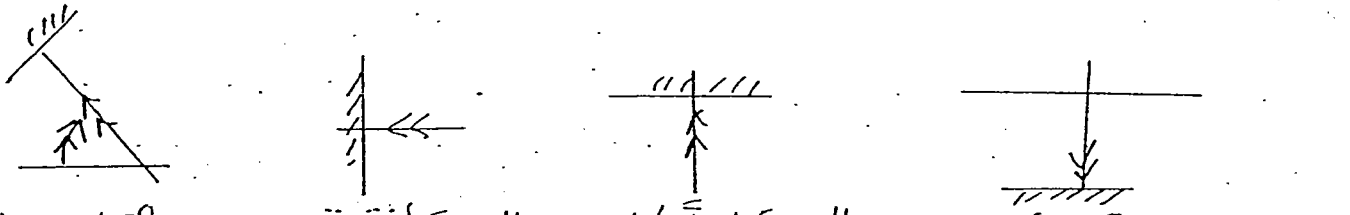


شكل (٣) : العلاقة بين سرعة النبضات و مقاومة الضغط للخرسانة

(31)

3- تذكر ⟸ Shmidt Hammer



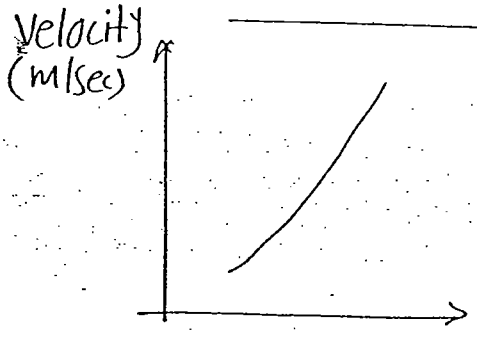


* أهم العوامل المؤثرة على قيمة رقم الارتداد :-

١- الخرسانة الكاملة القديمة يكون صلادة من داخلها لذلك يكون رقم الارتداد أكبر منها

٢- " الرطبة حديثة الصب " " أقل " " " " " " " أقل "

تذكر ⟸ Ultra sonic



* أهم العوامل المؤثرة على سرعة سريان الموجات فوق الصوتية :-

١- عمر الخرسانة.

٢- حديد التسليح. (يجب عمل تصحيح لسرعة الموجات بسبب وجود الحديد)

٣- معايرة العروة (زيادة معايرة العروة تزيد من سرعة سريان الموجات خلال الخرسانة)

Solution :-

* For schmidt Hammer

Footing	Ground beam	Column
$N_{average} = 28.33$	R.N$_{average}$ = 30.5	R.N$_{average}$ = 35.45
(From Fig. 1) = 0.0	α (From Fig. 1) = -90	α (From Fig. 1) = 0.0
f_c = 20 N/mm^2 = 200 kg/cm^2	$\therefore f_c$ = 30 N/mm^2 = 300 kg/cm^2	$\therefore f_c$ = 34 N/mm^2 = 340 kg/cm^2

: For ultrasonic

Transite Time average = 1.331 sec	Taverage = 0.068 sec	Taverage = 0.082 sec
= 3.0m	L = 0.25 m	L = 0.40 m
$V = \frac{3}{1.331}$ = 2.25 m/sec	$\therefore V = \frac{0.25}{0.068} = 3.66$	$\therefore V$ = 4.88 m/sec
$\therefore f_c$ → قليلة جداً	f_c قليلة جداً	f_c قليلة جداً
∴ جودة الخرسانة ضعيفة جداً	∴ جودة الخرسانة ضعيفة جداً	∴ جودة الخرسانة ضعيفة جداً

* ملحوظة اذا كان سرعة سريان الموجة (م/ث) ← ∴ جودة الخرسانة ممتازة ← أكثر من ٤٥٠٠
" " جيدة ← ٣٥٠٠ - ٤٥٠٠
" " ضعيفة ← ٢٠٠٠ - ٣٥٠٠
" " جداً ← أقل من ٢٠٠٠