CHAPTER 6

CONCLUSION

SECTION ONE
RUBBERIZED CONCRETE AT LOW VOLUME FRACTIONS

- **Cube compressive strength** is strongly affected by the change of the studied parameters and their levels. In general, as expected, the cube compressive strength decreases gradually with the increase in rubber content.

- Rubberized concrete yields a ductile mode of failure comparing to that of conventional concrete.

- The addition of silica fume increases the compressive strength significantly.

- The change in rubber type slightly affects compressive strength of rubberized concrete.

- For rubber surface treatment, the effect on compressive strength is hardly significant.

- From the effect of two factors interactions, the best compressive strength is obtained by the combination of these factor levels; C30 concrete grade, 0.5% rubber volume fraction and the addition of 10% silica fume as a replacement of cement by weight.

- The actual cube compressive strengths of the mixes, which are not included in the principle block, are very close to the calculated expected values from the classical method of analysis. Thus, the 1/9 fractional factorial of 3^5 design is applicable and can be used to predict the compressive strength or any other property conducted in the study for any treatment combination.

- For **slump test results**, rubberized concrete achieves slump varies from 10 mm to 60 mm as compared to 30 mm to 32 mm for control mixes without rubber.

- Rubberized concrete that contains rubber particles at 1.5% volume fraction gives slightly higher slump values than that of 2.5% rubber.

- Rubber type has the most significant effect on slump values. Fiber 8 yields high slump of 43mm as compared to 27mm and 17mm for crumb rubber and Fiber 4, respectively.

- The surface treatment of rubber particles has the least effect on slump values of the studied parameters.

- For **static modulus of elasticity**, almost all the rubberized concrete mixes yield lower static modulus of elasticity than the control mixtures.

- Rubber volume fraction has the most significant effect on the static modulus of elasticity, while rubber type has the lowest effect on the static modulus of elasticity.

- The results reveal that, the elastic modulus of rubberized concrete decreases gradually with increase in rubber content.

- **Impact resistance** of rubberized concrete improves significantly with the addition of rubber particles comparing to normal concrete.

- The impact resistance of rubberized concrete with fibrous rubber seems to be suitable for applications where high impact resistance is required.

- The surface treatment of rubber particles has the least effect on Impact resistance of the studied parameters.

- From the effect of two factors interactions, the best impact resistance is obtained by the combination of these factor levels; C30 concrete grade, 2.5% rubber volume fraction and the addition of 0.2% polypropylene fiber.

- **Flexural toughness** is also improved by the addition of rubber particles. Also the concrete mass was able to withstand loads even when it was highly cracked.

- Rubber type has a significant effect on flexural toughness, as rubber fibers yield to improve flexural toughness of rubberized concrete.

- From the effect of two factors interactions, the best flexural toughness is obtained by the combination of these factor levels; C30 concrete grade, 2.5% rubber volume fraction and the addition of 0.2% polypropylene fiber.

- For **abrasion resistance**, all rubberized concrete mixes have abrasion resistance comparable to control mixtures.

- Rubberized concrete with crumb rubber yields the best abrasion resistance comparing to that of rubber fibers.

- The addition of silica fume enhances the abrasion resistance of rubberized concrete significantly.

SECTION TWO

In the second section of the research, rubber was used at high portions in concrete as sand replacement by volume. Also, the properties of rubber-cement and rubber-epoxy composites were investigated.

RUBBERIZED CONCRETE AT HIGH VOLUME FRACTIONS OF SAND REPLACEMENT

- **Thermal conductivity** decreases significantly with the increase in rubber content for rubberized concrete, as the reduction in k-value at 100% fine aggregate replacement is 58.6%.

- The ACI model for thermal conductivity of concrete is not applicable for rubberized concrete as the actual k-values are lower than the values derived from the ACI model.

- The implementation of rubber particles into concrete improves the **sound insulation** properties by 69% at 100% fine aggregate replacement.

- The maximum reduction in **density** was recorded by 20% at 100% replacement of fine aggregate. Also, the absorption increases with the increase in rubber content.

- **Compressive strength** decreases significantly when rubber particles are used as fine aggregate replacement. The maximum reduction in compressive strength for rubberized concrete is 93% at 100% fine aggregate replacement.

- **Impact resistance** yields the same reduction for rubberized concrete.

- Despite of the reduction in impact resistance, the number of blows corresponding to the crack propagation improves with the increase in rubber content.

- **Flexural strength** of rubberized concrete decreases significantly with the increase in rubber content. Furthermore, large deformations are recorded for rubberized concrete, especially at high rubber contents.

RUBBER-CEMENT AND RUBBER-EPOXY COMPOSITES

- Rubber composites have distinguished **thermal and sound insulation** properties. As the average thermal conductivity of rubber-cement and rubber-epoxy composites are 0.47 and 0.25, respectively.

- The sound attenuation coefficient of rubber-cement and rubber-epoxy composites varies significantly with the change in rubber type.

- The average **dry unit weight** of rubber-cement and rubber-epoxy composites are 1200 and 900 kg/m^3, respectively. Thus rubber composites may be considered as a lightweight material, based only on the unit weight test results.

- Rubber-epoxy composites exhibit a significant **elastic behavior** especially for Fiber 8 and Fiber 4 as it retains to its original dimensions after unloading. Thus, it may be suitable to be used as contraction and expansion joints.

RECOMMENDATIONS

- It is recommended to study the durability properties of rubberized concrete at low volume fractions with different types of rubber particles, as rubberized concrete seems to be promising in terms of freezing and thawing resistance.

- Further investigation is needed to study the damping capacity of rubberized concrete at different rubber contents, as rubberized concrete is expected to improve the damping capacity of concrete.

- The new composites of rubber-binder, especially rubber-epoxy, conducted in this investigation are very promising in terms of sound and thermal insulation, so more investigation is required to determine other properties like sound absorption, damping capacity and impact resistance. Also, more investigation is required for rubber-epoxy composites to predict its behavior as contraction and expansion joints.

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رساله علميه مقدمة الى

قسم الهندسة الإنشائية
كلية الهندسة - جامعة الإسكندرية

استيفاء لمتطلبات الحصول على درجه

الماجستير في العلوم

في

الهندسة الإنشائية

مقدمة من

م / مصطفى محمد عبد الباسط محمد كامل

بكالوريوس الهندسة المدنية - كليه الهندسه - جامعة الإسكندرية

2010

تقديم :2015

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استخدام بودرة المطاط الناتج من الاطارات فى الخرسانة كمادة انشائية

رساله مقدمة من

م / مصطفى محمد عبد الباسط محمد كامل

استيفاء لمتطلبات الحصول على درجه

الماجستير في العلوم
في
الهندسة الإنشائية

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ملخص البحث

استخدام بودرة المطاط الناتج من الاطارات فى الخرسانة كمادة انشائية

- **المقدمة:**

الهدف الرئيسى من هذا البحث هو اعاده استخدام حبيبات المطاط الناتجه من تقطيع الاطارات المستعمله فى تطبيقات مختلفه فى مجال الهندسه المدنية. حيث انه يوجد كمية هائلة من الاطارات المستعمله التى ليس لها استخدام و يوجد صعوبه فى التخلص منها او اعادة استخدامها. وبناء على الدراسات السابقه تم إجراء عده طرق لإستخدام حبيبات المطاط الناتجه من تقطيع الاطارات فى انتاج الخرسانة المطاطية و كذلك تم عمل مركبات جديدة من المطاط والاسمنت والمطاط والإيبوكسي بغرض استخدامها فى التطبيقات الغير انشائية.

الباب الأول:

يعرض حجم المشكلة البيئيه التى يعانى منها العالم و بالأخص دول العالم الثالث من تراكم مخلفات الاطارات و تزايدها سنويا. و كذلك يشمل مقدمة عن أسباب استخدام حبيبات المطاط فى الخرسانة.

الباب الثانى:

يقدم نظرة عامه عن كميات مخلفات الاطارات فى دول العالم المختلفة وبالتحديد فى مصر و كذلك يتناول مكونات المطاط و الطرق المتعارف عليها عالميا فى إعاده تدوير مخلفات الاطارات. أيضا تم ذكر الدراسات السابقه المختصة بإعادة تدوير حبيبات المطاط فى الخرسانة و مدى تأثيرها على خواص الخرسانة المختلفة.

الباب الثالث:

يختص بالبرنامج العملى و خواص المواد التى تم استخدامها فى البحث من أسمنت و ركام خشن و ركام ناعم و كذلك الياف البولى بروبيلين و حبيبات السيليكا فيوم و حبيبات المطاط و الطرق المستخدمة للمعالجة السطحيه لحبيبات المطاط. الجزء الأول من البرنامج العملى يعرض نسب الخلط والاختبارات التى تم اجراؤها للخرسانة المطاطية والتى تم فيها استخدام حبيبات المطاط بنسب ضئيلة كإضافة للخرسانة. و تم عرض تصميم الخلطات لهذا الجزء باستخدام طريقة تصميم التجارب بالتحليل الجزئى.
و المتغيرات المختلفة التى تم دراسة تأثيرها على خواص الخرسانة المختلفة هى :

- **تأثير تغير رتبه الخرسانه (رتبة 20 و 25 و 30)**
- **تأثير تغير نسبه اضافه حبيبات المطاط (0.5% و 1.5% و 2.5%)**
- **تأثير الاضافات المختلفة على الخرسانه المطاطية (الياف البولى بروبيلين و حبيبات السيليكا فيوم)**
- **تأثير تغير شكل حبيبات المطاط (حبيبات كرويه مقاس 4 مم و الياف مقاس 2.35 مم و الياف مقاس 4.75 مم)**
- **تأثير نوع المعالجة السطحيه لحبيبات المطاط (المعالجه بمحلول قلوى NaOH والمعالجه ببولى فينيل اسيتاتPVA)**

و الجزء الثانى من البرنامج العملى يتناول استخدام حبيبات المطاط كإحلال للركام الناعم بنسب كبيرة فى الخرسانة و كذلك خواص المواد المستخدمة فى مركبات المطاط مع الاسمنت و المطاط مع الايبوكسى. ويشمل أيضا تفصيل نسب الخلط و التجارب التى تم اجراؤها لدراسة الخواص المختلفة.

الباب الرابع:

يختص بعرض و تحليل النتائج للاختبارات التى تم إجراؤها على الخرسانة المطاطية التى تحتوى على نسب ضئيلة من حبيبات المطاط المختلفة. و تم تحليل النتائج باستخدام طريقة تصميم التجارب بالتحليل الجزئى و تم عرض النتائج بالتفصيل و تأثير تغير كل عامل على خواص الخرسانة المطاطية. كذلك تم دراسة تأثير التداخل بين العوامل المختلفة على خواص الخرسانة و عرض كل مما سبق بشكل كافى بطريقة الجداول و المنحنيات. و كذلك تم استنتاج نتائج الخلطات التى لم يتم تنفيذها و هى 216 خلطة. كما تم عمل تجارب لبعض هذه الخلطات و مقارنتها مع النتيجة المستنتجة و كانت نسبة الخطأ فى حدود من 4 الى 10%.

الباب الخامس:

و يختص بدراسة وتحليل النتائج الخاصة بالاختبارات التى تم اجراؤها على الخرسانة التى تم استخدام حبيبات المطاط فيها كإحلال بالحجم للركام الناعم. كذلك يشمل الباب تحليل نتائج الاختبارات الخاصة بمركبات المطاط مع الاسمنت والمطاط مع الإيبوكسى.

الباب السادس:

و يشمل ملخص لأهم الاستنتاجات التى تم التوصل اليها من الاختبارات المختلفة التى تم اجراؤها خلال البحث والتى من بينها:

- **بالنسبة للخرسانة المطاطية التى تحتوى على حبيبات المطاط بنسب ضئيلة:**

1 - يمكن اضافة حبيبات المطاط بنسب صغيرة الى الخرسانه بدون حدوث انخفاض كبير فى مقاومة الضغط خصوصا فى الخرسانة ذات الرتب العالية. لأن الانخفاض فى المقاومة يزيد بشكل ملحوظ مع زيادة نسبة المطاط فى الخرسانة.

2 - تحسن ملحوظ فى مقاومة الخرسانة مع اضافة السيليكا فيوم نظرا لنعومه حبيباته مقارنة بالأسمنت مما يزيد من قوة الترابط مع حبيبات المطاط.

3 - التغير فى شكل حبيبات المطاط و طريقة المعالجة ليس له تأثير ملحوظ على مقاومة الضغط مقارنة بالعوامل الأخرى.

4 - تم تسجيل انخفاض ملحوظ فى معاير المرونة الاستاتيكى للخرسانة المطاطية مقارنة بالخرسانة العادية خصوصا مع زيادة نسبة المطاط فى الخرسانة.

5 - تحسن كبير فى مقاومة الخرسانة للصدم مع زيادة نسبه المطاط فى الخرسانة خصوصا مع استخدام ألياف المطاط ذات مقاس 4.75 مم.

6 - متانة الخرسانة المطاطية تزيد عن الخرسانة العاديه نظرا لتحملها اجهادات اضافية حتى بعد تعرضها للشروخ نتيجة التحميل. و تم ملاحظة ان ألياف المطاط ذات المقاس الاكبر تعطى أفضل النتائج مقارنة بالأنواع الاخرى من حبيبات المطاط.

- **و بالنسبة للخرسانة المطاطية التى تحتوى على نسب كبيرة من حبيبات المطاط كإحلال للرمل:**

1 - تم تسجيل انخفاض كبير فى جميع الخواص الميكانيكية للخرسانة مع زيادة نسبة احلال المطاط للركام الصغير و أن الانخفاض فى مقاومة الضغط قد يصل الى أكثر 90% عند نسبة إحلال 100%.

2 - بالرغم من الانخفاض فى الخواص الميكانية للخرسانة المطاطية عند استخدام نسب إحلال كبيرة إلا انها اظهرت تحسن ملحوظ فى خواص العزل للصوت و الحرارة.

- **و بالنسبة لمركبات المطاط مع الاسمنت و المطاط مع الإيبوكسى:**

1 - تبين من الدراسة امكانيه استخدام مركبات المطاط والاسمنت و مركبات المطاط والايبوكسى كمواد جيدة للعزل الصوتى و عزل الحرارة.

2 - وكذلك تم التوصل الى امكانية استخدام مركبات المطاط و الايبوكسى فى الفواصل الانشائية نظرا لمرونتها الفائقة.