EFFECT OF AGGREGATE PROPERTIES ON HOT MIX ASPHALT PERFORMANCE

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ABSTRACT

Mineral aggregates make up 90 to 95% of a HMA mix by weight or approximately 75 to 85% by volume. The properties of the mineral aggregates have significant affects in performance of our local roadways which offers the possibility of investment in these properties towards resisting different ranges of external applied loads and environmental conditions. For this reason, the performance properties susceptibility due to aggregate properties (Consensus and Source) is going to be evaluated with a wide range of blends, fine, medium and coarse gradation mixtures. The selected source property in this study was toughness (% abrasion), and the consensus property used in this study was angularity (% crushed). Results show that the medium graded mixtures were more susceptible in terms of Marshall Stability due to the change in % abrasion and % crushed aggregate, while the coarse graded mixtures were more susceptible in terms of Marshall Flow due to the change in % abrasion and % crushed aggregate.

Keywords: % Los Angeles abrasion, %Crushed, Marshall Stability, Marshall Flow, Air Voids

تأثير خواص الركام على اداء الخلطة الاسفلتية الحارة

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الخلاصة

يشكل الركام حوالي 75 % الى 85 % من حجم الخلطة الاسفلتية الحارة و 90 الى 95 % من وزن الخلطة. ونوعية الركام المعدني له تاثير كبير على اداء طرقنا المحلية، والذي يوفر امكانية استثمار هذه الخواص باتجاه مقاومة مختلف مديات القوى المسلطة الخارجية والظروف البيئية. لهذا السبب اصبح من الضروري تقييم تأثرية الخواص الادائية للخلطة الاسفلتية نتيجة التغيير في خواص الركام (الخواص المصدرية والخواص المتفق عليها) باستعمال مجال واسع من التدرجات الناعمة والمتوسطة النعومة (الكثيفة) والخشنة. وفي هذه الدراسة تم تقييم خاصية المصدر بالاعتماد على خاصية القساوة وتقييم

خاصية الركام المتفق عليها وهي التزاوي . اظهرت نتائج الدراسة بان الخلطة الاسفاتية ذات التدرج الكثيف تتأثر بشكل اكبر بتغيير خواص الركام من ناحية ثباتية مارشال. اما الخلطة الاسفلتية ذات التدرج الخشن فقد اظهرت تاثرية اكبر عند تغيير خواص الركام من ناحية جريان مارشال.

INTRUDUCTION

Asphalt concrete (AC) is a heterogeneous material that consists of asphalt cement, natural or artificial aggregate, mineral filler, additives and air voids. Aggregate comprise the vast bulk of paving mixture and therefore, exert significant influence on the resulting engineering properties of the structure. The fundamental measurements of aggregate morphological properties (angularity, shape, surface texture and toughness) are essential for good quality control of aggregates and for understanding the influence of these properties on the behavior of asphalt (Khandhal and Parker, 1998). In ASTM D8 (ASTM 2003), aggregate is defined as " a granular material of mineral composition such as sand, gravel, shell, slag, or crushed stone, used with cementing medium to form mortars or concrete or alone as in base course, railroad ballasts, etc." (Fwa, 2006).

OBJECTIVE AND TEST PLAN

The objective of this study was to evaluate the effect of aggregate properties (Toughness and Angularity) on Marshall Properties for HMA mixture (stability, flow, and air voids). To accomplish this, various mixtures were compacted with optimum asphalt content and three different gradation types. Variable values of percent Los Angeles Abrasion (Source Property) were used throughout this study which refers to the different quarry in Iraq. Different percentages of crushed aggregate (consensus property) were also used for all three gradation types. The same compactive effort 50 blows/face was used to determine their volumetric and performance-related properties. In order to consider a range of mixtures, three blends of fine, medium and coarse gradations limited by the ASTM specification for gradation were used and shown in **Figure 1**. Three source of aggregates from Al-Nebaey, daqooq, and Al-Akhaither were used and their determined properties were shown in **Table 1**, and one grade (40-50) penetration graded of asphalt cement were utilized from daurah refinery, and its properties were shown in **Table 2.**

Coarse Aggregate Properties:

Coarse aggregate is the material, which is substantially retained on No. 4 sieve (2.365 mm). Generally, the asphalt concrete mixture contains from 35-65 percent of coarse aggregate for a nominal maximum size of 19.0 mm. This content normally gives a suitable texture for a heavily trafficked road (ASTM, 2003).

The most significant properties of graded coarse aggregate to be used in the manufacture of asphaltic mixtures are: (Superpave, 1994)

A. Consensus properties which are critical properties required to develop a desirable HMA mix. These properties are:
   - Flat and Elongated Particles

- Aggregate Angularity (Coarse and Fine)
- Clay content

B. Source properties, which are critical also, including:

- Effective Specific Gravity and Asphalt Absorption.
- Toughness
- Soundness
- Deleterious materials
- Mineral Composition

Two significant important properties were considered as factors affecting the performance of HMA mix.

Coarse Aggregate Angularity

Coarse aggregate angularity is defined as the percent by weight of aggregate retained on the No.4 (4.75 mm) sieve with one or more fractured face. This property is determined using ASTM D5821 "Standard Test Method for Determining the Percentage of fractured Particles in Coarse Aggregate" (ASTM, 2003). This property ensures a high degree of aggregate internal friction and rutting resistance. The HMA mixtures containing different aggregates types were evaluated by Ishai and Gelber for Marshall Stability and flow, resilient modulus, and split tension strength. The results showed that there was a significant increase in the stability with the increase in the geometric irregularities of the aggregates. There was no correlation between geometric irregularities and resilient modulus or split tension strength of the HMA mixtures. (Ishai and Gelber, 1982)

In 1962, Huang developed the particle index test for evaluating particle shape and surface texture. Particle index is determined by rodding aggregate in a mold and determining the voids. The particle index is then derived as follows: (Huang, 1962)

$$\mathbf{I_a = 1.25\, V_{10} - 0.25\, V_{50} - 32\%} \qquad \mathbf{(1)}$$

Where;

I_a= the particle index value

V_{10}= % voids in the aggregate sample compacted with 10 blows per layer

V_{50}= % voids in the aggregate sample compacted with 50 blows per layer

The results indicate that the test method is capable of distinguishing the difference between natural rounded and rough angular aggregate by increasing particle index value. This test has been standardized as ASTM D3398, index of aggregate particle shape and texture.

Toughness (% L.A. Abrasion)

Toughness is the percent of material from an aggregate blend during the Los Angeles abrasion test. This property is determined using (ASTM C131) "standard Method of Test for Resistance to Degradation of Small-size Coarse aggregate by Abrasion and Impact in the Los Angeles Machine". This test provides some indication of the aggregate's ability to resist degradation from processes that it would encounter through its life as an aggregate in HMA. HMA aggregates can be degraded during stockpiling, processing (through a HMA plant), placing, compacting, and may due to traffic loads.

Aggregate which lack adequate toughness and abrasion resistance may cause construction and performance problems. Degradation occurring during production can affect the overall gradation, and thus, widen gap between properties of the laboratory designed mix and field production [Yiping, et.al, 1998].

RESULTS OF EXPERIMENTAL WORK

The optimum asphalt content by the Marshall Mix design method for three blend mixtures, and designations for each mixture used in the remaining discussion are provided in **Table 3**.

Effect of Los angeles Abrasion of Aggregate

Mixture performance to percent of wear variation is illustrated in **Figures (2,3,4)** for the three target mixtures considered (fine, medium, and coarse). Over an increase of percent Los Angeles Abrasion from (12.1-to-20.1-to-26.5), the medium gradation mixture was more susceptible to increase in percent Los Angeles Abrasion of aggregate. Changing the percent Los Angeles Abrasion from 12.1 to 26.5 revealed a decrease in Marshall Stability by 1.88 kN, whereas, the coarse gradation shows less susceptibility and reveals less decrease in Marshall Stability by 0.93 kN, as shown in **Figure 2**.

Figure 3 shows that the increase of percent Los Angeles Abrasion of aggregate will decrease the Marshall Flow for all gradation mixtures used in this study. The medium gradation mixture revealed less decrease in Marshall Flow (about 0.26 mm) than do the coarse gradation mixture which decreased by 0.428 mm.

Figure 4 shows the effect of Percent Los Angeles Abrasion of aggregate to % air voids. In this figure the fine gradation mixture revealed less decrease in % air voids and the variance was 0.15 % , while the coarse and medium gradation show more variation in % air voids, which revealed as twice as the fine gradation reveals.

Effect of Crushed of Aggregate

Mixture performance to percent of crushed aggregate variation is illustrated in **Figures (5,6,7)** for the three target mixtures considered (fine, medium, and coarse) gradations.

Figure 5 shows that the an increase of percent crushed in aggregate from 0 % -to- 20 % - to – 40 % will increase the Marshall stability for the three gradation mixtures, and the medium gradation mixture was more influenced by the increase in % crushed, and the variance was 1.4 kN. While the coarse graded mixture shows less influencing to the increase in % crushed, and the variance was 0.72 kN

Figure 6 shows that the increase of %percent crushed in aggregate from 0 % - 20 % - to – 40 % will decrease the Marshall flow for all gradation mixtures used. Fine and medium graded mixtures show less susceptibility to the change in percent crushed and the decrease was about 0.22 mm as average, while the coarse graded mixture was more susceptible to the increase in percent crushed in aggregate, and the change in Marshall Flow was 0.42 mm.

Figure 7 shows that the increase of percent crushed in aggregate from 0 % - 20 % - to – 40 % will decrease the percent air voids for all gradation mixtures used in this study. The results show that the fine graded mixture was more susceptible to the change in percent crushed of aggregate, and the decrease value was 0.96 %, while the coarse graded mixture shows less susceptibility to the change of % crushed and the value of the decrease was 0.68 %

CONCLUSION

Within the limitations of materials and test used in this study the following conclusions are drawn:

1- The medium graded mixtures were more susceptible to the increase of percent Los Angeles Abrasion, measured by the Marshall stability.
2- The course graded mixtures evaluated were more susceptible to the increase of percent Los Angeles Abrasion, measured by the Marshall Flow and percent Air Voids.
3- The medium graded mixtures were more susceptible to the increase in percent crushed aggregate, measured by the Marshall stability.
4- The coarse graded mixtures were more susceptible to the increase of percent crushed, as measured by the Marshall flow.
5- The fine graded mixture was more susceptible to the increase in percent crushed aggregate, measured by the percent Air Voids.

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Table 1: Physical Properties of Aggregate.

properties	ASTM	SORB*	Al-Akhaither	Nebaey	Daqooq
Bulk Specific Gravity	C 127		2.639	2.568	2.614
% Wear (L.A. Abrasion)	C 131	<=35	12.1	26.5	20.1

*: Iraqi Standard Specification for Roads and Bridges

Table 2: Physical properties of asphalt cement (Yaqob, 2004)

Test	Unit	ASTM	Results D(40-50)
Penetration 25^0 C, 100 gm, 5 sec.	1/10 mm	D 5	42
Absolute Viscosity at 60 ^{0} C	Poise	D 2171	3068
Kinematic Viscosity at 135 ^{0} C	C St.	D 2170	373
Ductility (25 ^{0} C, 5 cm/min.)	Cm	D 113	> 100
Softening point (Ring & Ball)	C^0	D 36	51.0

Specific gravity at 25^0 C	…….	D 70	1.04
Flash point (Cleveland Open Cup)	C^0	D 92	332
After Thin- Film Oven Test			
Penetration of Residue	1/10 mm	D 5	39
Ductility of Residue	Cm	D 113	82
Loss on Heat at 135^0C, 50 gm, 5 hrs	%	D 1754	0.82

Table 3: Type of Aggregate Gradation and Optimum Asphalt Content for Mixtures

Gradation Type (**SORB**)	Optimum AC (%)	Designation
Lower Limit (Coarse)	4.6	Coarse
Average Limit (Medium)	4.9	Medium
Upper Limit (Fine)	5.2	Fine

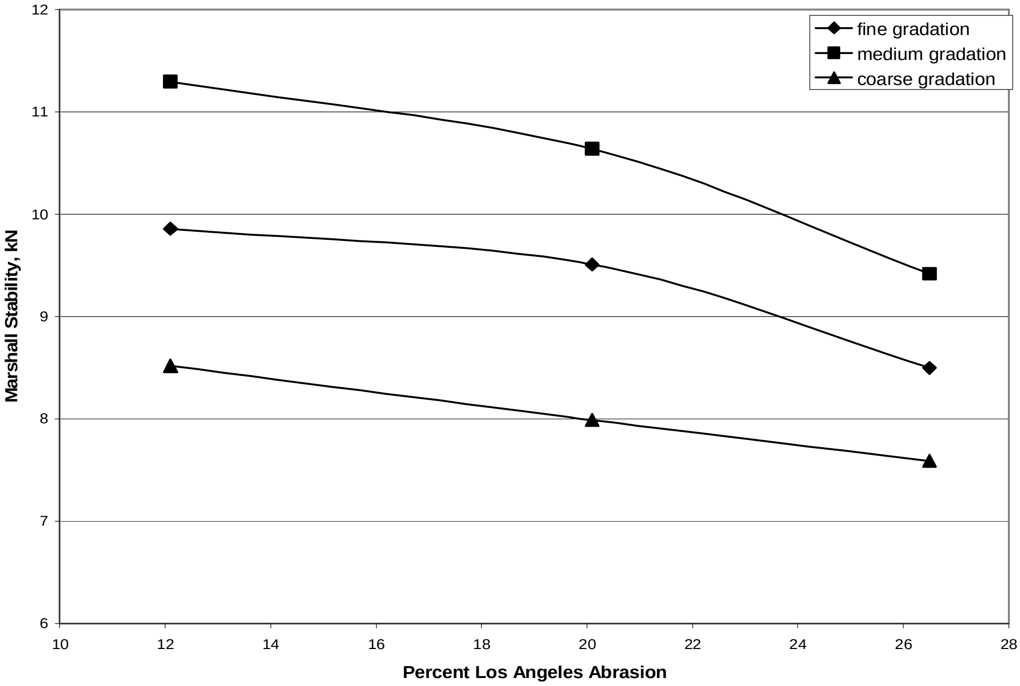

Figure 2: Marshall Stability Variation due to changes in Percent Los Angeles Abrasion

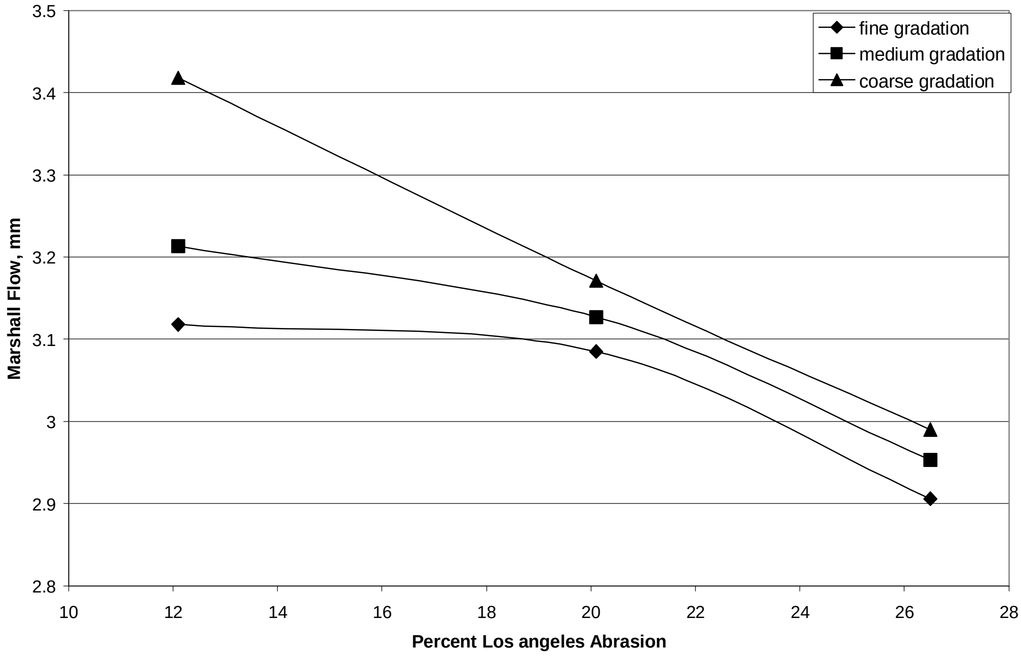

Figure 3: Marshall Flow Variation due to changes in Percent Los Angeles Abrasion

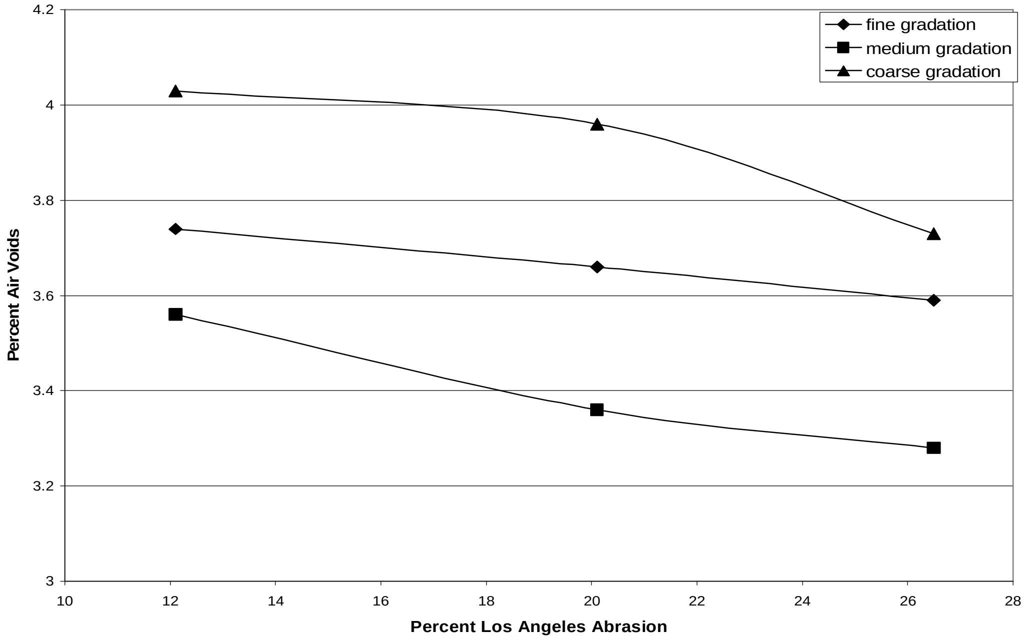

Figure 4: Percent air Voids Variation due to changes in Percent Los Angeles Abrasion

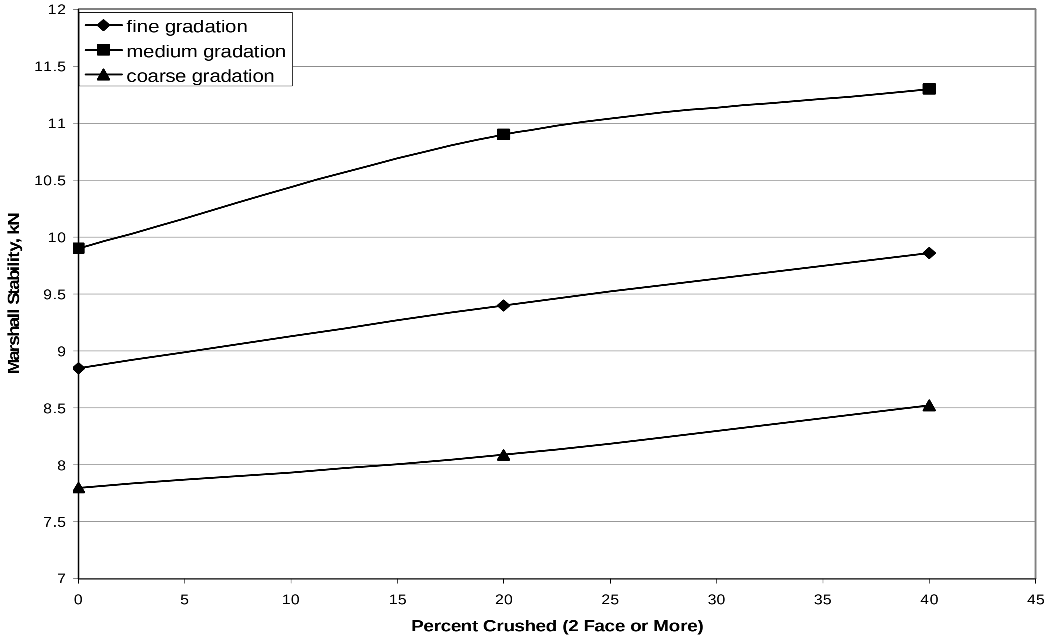

Figure 5: Marshall Stability Variation due to changes in Percent Crushed of Aggregate

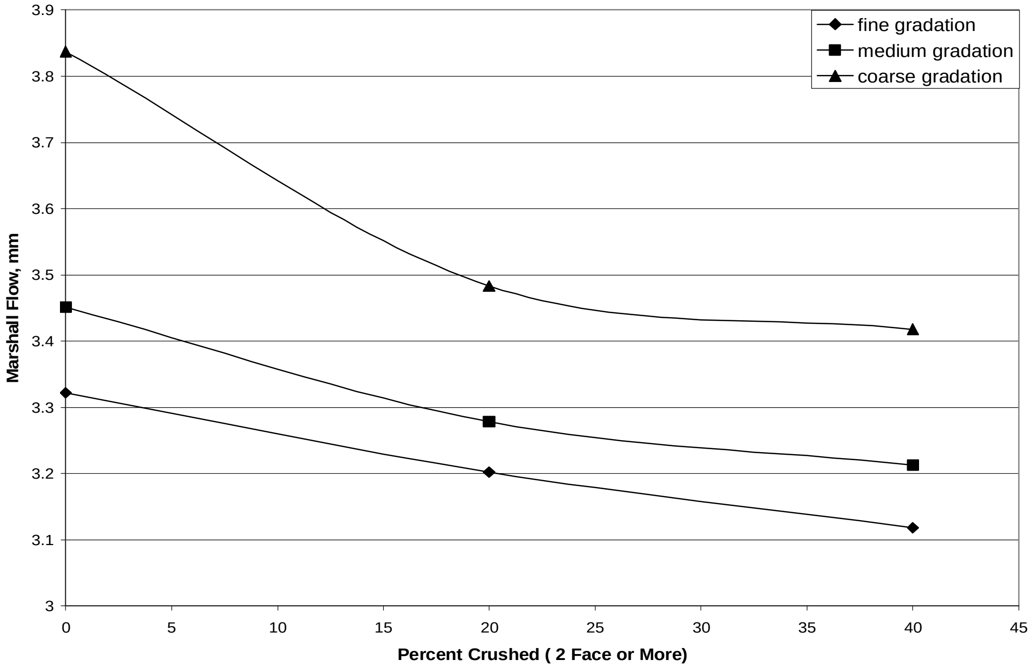

Figure 6: Marshall Flow Variation due to changes in Percent Crushed of Aggregate

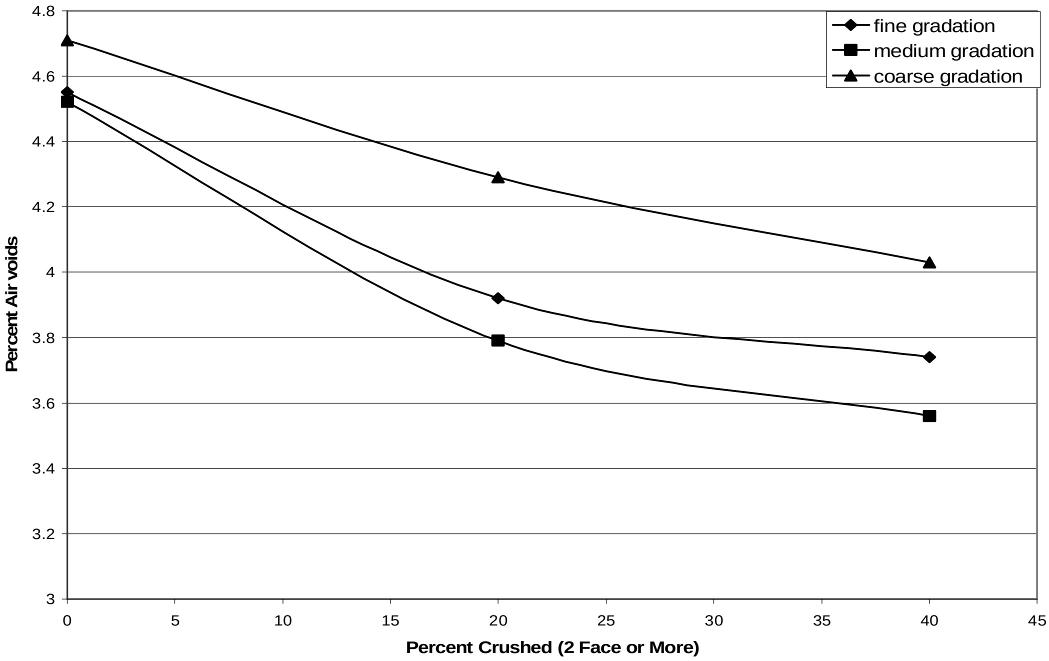

Figure 7: Percent Air Voids Variation due to changes in Percent Crushed of Aggregate