Stress-Strain Relationship of Polymer Modified No-Fine Concrete

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الخلاصة :

ان استخدام الخرسانة الخالية من الركام الناعم في المنشات قد زاد بصورة خاصة خلال او بعد السبعينات. لقد تم في هذا البحث الحصول على خرسانة جديدة من الخرسانة الخالية من الركام الناعم وذلك باضافة بوليمر مطاط الستايرين- بيوتادين كنسبة من محتوى السمنت.يتضمن البحث دراسة تأثير هذا البوليمر على علاقة الإجهاد- الانفعال للخرسانة تحت الانضغاط. كانت الخلطات الخرسانية بنسب وزنية (١:٧، ١:٦، ١:٥، ١:٤) سمنت: ركام . أضيف البوليمر كنسبة وزنية من السمنت ب(٥، ٧,٥ و ١٠%) و تم عمل الخرسانة المرجعية و مقارنتها ازاء كل حالة.تم اقتراح نموذج رياضي جديد للأجزاء الصاعدة والنازلة من مخطط الإجهاد- الانفعال. وقد وجد إن المساحة تحت منحنى الإجهاد- الانفعال للخرسانة الخالية من الركام الناعم المطورة بالبوليمر اكبر من تلك للخرسانة المرجعية وتزداد بزيادة نسبة البوليمر/ السمنت. لقد تم التأكد من ان الخرسانة الخالية من الركام الناعم والمطورة بالبوليمر مناسبة كخرسانة انشائية وخاصة للنسب السمنت / الركام (١:٤ و ١:٥) .

Abstract

The use of no-fines concrete in construction increased especially during and after 1970s. New concrete is obtained from no-fines concrete in this research by adding **S**tyrene **B**utadiene **R**ubber (SBR) Polymer as a ratio of cement content.

This research includes the study of the effect of SBR polymer on stress-strain relationship of concrete under compression.

The concrete mixes by weight were (1:7, 1:6, 1:5, and 1:4) cement / aggregate (C/A). The polymer was added as percentages by weight of cement as (5, 7.5 and 10%). Rreference mixes were made for every case.

A new mathematical model for both ascending and descending portions is suggested in this research and discussed.

The area under the stress-strain curve was found in polymer modified no-fines concrete to be greater than reference concrete and was increased with polymer / cement ratios (P/C).

The suitability of no-fine polymer concrete to be used in structural members has been affirmed in this research especially for (1:4 and 1:5) C/A polymer mix.

1. No-Fines Concrete

No-fines Concrete means concrete composed of cement and coarse aggregates of (9-19) mm maximum size; the product has many uniformly distributed voids [1,2] .

"No-fines concrete" is used for load bearing external and internal walls, non-load-bearing walls, infilling walls for framed structures single or multistory buildings, also this type of concrete has been used for temporary structures because of low initial cost.

This type of concrete has a higher thermal insulating property. It can be used for external walls for heat insulation and because of rough texture it gives a good base for plastering. This type of concrete reduces the total load of the structure and gives low cost of construction.

Another advantage of using this construction material is that even if the outside surface of the no-fines concrete wall is subjected to rain beating, the inside of the wall will be free from dampness because of low capillary action on account for large voids; thus, no fines concrete become a popular construction material.

"No-fines conerete" is classified as lightweight cencrete of mixes (1:6-1:10) having low density less than 2200 kg/m^3[1].

This type of concrete is characterized by it's low strength in addition to low bond strength if it is used as a structural member.

2. Research Signficance

The aim of this work is to investigate the improvement in properties of no-fines concretes through the inclusion of (SBR) polymer. This study includes wide-range experimental investigations of stress-strain relationship for both ascending and descending portions for different mixes ranged from 1:4 to 1:7 (cement / aggregates) and using different (polymer / cement) ratios in these mixes. Mathematical models are attempted and generalized on this type of concrete with different mixes.

3. Stress-strain Relationship of concrete

The knowledge of behavior of concrete such as stress-strain relationship under loading is very important to calculate the deflection of structures and design of concrete members with respect to their section, quantity of steel and stress analysis.

The behavior of concrete is quite complex because this behavior depends on rate of loading, materials properties and proportions, chemical and physical characteristics of materials, curing conditions, dimensions of specimens, etc.

4. Stress-Strain Relationship for Polymer Concrete

Rapid setting organic polymers is used in Polymer Concrete (PC) as binders [(3)], the most popular binders currently in use are epoxy, polyester, and methyl methacrylate. Studies on epoxy and polyester polymers have shown that the strength, failure strain, failure mode and stress-strain relationships are influenced by curing method and strain rate[(4-6)] .

Haddad, David and Paul [(7)] studied the strength of methylmethacrylate polymer concrete and concluded that casting temperature, testing temperature, aggregate type, and gradation had varying effects on the strength. However the data on epoxy PC and polyester PC are rather limited and there is increasing interest in the deformation of characteristics and stress-strain relationship of PC systems.Their work [(7)] demonstrates the ductile and brittle nature of polymers and PC, and found that there is a greater percentage of reduction in polymer compressive strength and modulus of elasticity with an increase in temperature than in PC

5. Program Layout

The program layout is shown in Fig.(1):

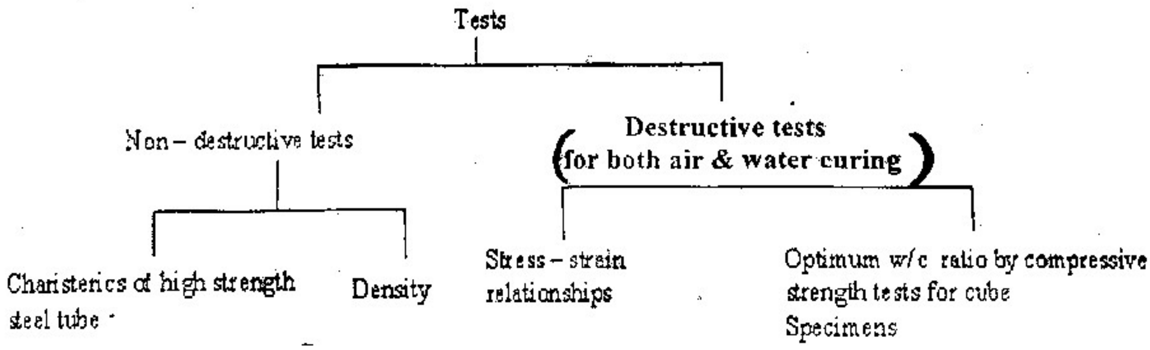

Fig. (1) Experimental program of this work

5.1 Materials

5.1.1 Cement

Cement type I (OPC) of Kubaisa factory for cement production was used in this work; chemical compositions of this type is shown in table (1).

Table (1) Chemical composition of Ordinary Portland cement**

No.	Oxide Chemical composition	Chemical composition Weight %	IQS 5 : 1984 Limits %
1	CaO	62.5	
2	SiO_2	21.3	
3	Fe_2O_3	3.07	
4	Al_2O_3	4.96	
5	SO_3	2.26	2,8*
6	Mgo	3.1	5,0*
7	L.O.I	1.45	4.0*
8	Insoluble Residue	0.7	1.5*
9	L.S.F	0.9	0.66-1.02
10	C_3S	49.5	
11	C_2S	23.4	
12	C_3A	7.8	
13	C_4AF	9.4	

**** The values were obtained from Kubaisa cement factory.**
*** Maximum limits.**

5.1.2 Coarse Aggregates

Graded coarse aggregates from Al-Jarayishi region in Al- Anbar governorate was used which were shown conforming to (B S 882)[8] , see table (2).

Table (2) Sieve analysis of coarse aggregate

Sieve size (mm)	Percent passing by weight
20	100
10	94.02
5	13.08
2.36	1.42

5.1.3 Water

Tap water was used in all mixes.

5.1.4 Polymers

Styrene butadiene rubber was used in this work. The chemical composition of which is shown in table (3). The polymer (SBR) was used as a ratio by weight of cement of 5%, 7.5% and 10%.

Table (3) Chemical composition of Styrene butadiene rubber (SBR)*

Infra-Red (I.R.) test	pH%	Water Content%	Solid Particles Content%
Styrene Butadiene Rubber with small percentage of admixtures	8.2	42.4	57.42

*** The test was done in Ibn-Rushd industrial company**.

6. Concrete Mixing Procedure

A mechanical mixer of the capacity ($0.1m^3$) operated by electrical power was used. Aggregates were added before adding the cement.

After adding the cement, the mixer turned on with adding water according to water/cement ratio, then (SBR) polymer was added to the homogenous mix and the mixing was continued until all particles are fully coated with (polymer-cement paste) matrix ; also the final mix should have a uniform or a homogenous color.

Ohama[9] adopted this procedure under title"Modification with liquid polymers", also this mixing procedure was illustrated by Radomir [10].

As no-fines concrete does not pose any problem for compaction after adding it in moulds, using simple rodding is sufficient for full compaction. Also vibration is not required.

Thus, the mixing after putting it in moulds in three layers (it should be noted that each layer must be subjected to 25 strokes for 100 mm cubic mould specimens, and not less than (30) strokes for cylinder moulds). The top surface should be uniform . Then moulds should be opend after (24) hrs and cured until testing time.

7. Capping Requirements

Capping is done in this work for all cylinder specimens, in order in obtain uniformly distributed load under applied load, and also to obtain accurate readings.

The capping was done after (4hrs) of casting, so that concrete in cylinder mould undergoes plastic shrinkage and subsidesfully.

The capping was made by means of cement paste and by glass plate of about 7mm in thickness and of a length of about (diameter of cylinder + 30mm). [1]

8. Curing

Both water and air curing were used in this study. Specimens of dimensions (150×300 mm) were cured in water for 26 days. Also, cylindrical specimens of dimension (75×150mm) were used for constructing complete stress-strain relationship. Two specimens were tested for each mix.

The average temperature for curing was 20^{o}C, specimens were kept dry before testing. It was shown that wet specimen shows a higher modulus of elasticity [11] .

The best method for curing was the air curing. Radomir and Radonjanin [10] illustrate the best method for curing of polymer modified concrete, see Fig (2). The same method was used in this work for curing which was (6) days in water and (22) days in air. Cylindrical specimens with dimensions of (75×150 mm) were used in this study.

9. Mix Proportions

The mix proportions used in this study were 1:4 (cement: coarse aggregates) 1:5, 1:6, and 1:7 with different polymer / cement ratios by weight of 5%, 7.5 % and 10%. Reference mixes were investigated in every case.

10. Stress-strain Test for the Ascending Portion

Mechanical strain gauges of effective length equal to (150 mm), type ELE and designated for (150×300 mm) cylindrical specimens only,were used for determination of strain in this test.

The test was carried out according to (ASTM-C-469) [12] Strain values were obtained by dividing cach dial gauge reading by the effective length of the gauge.

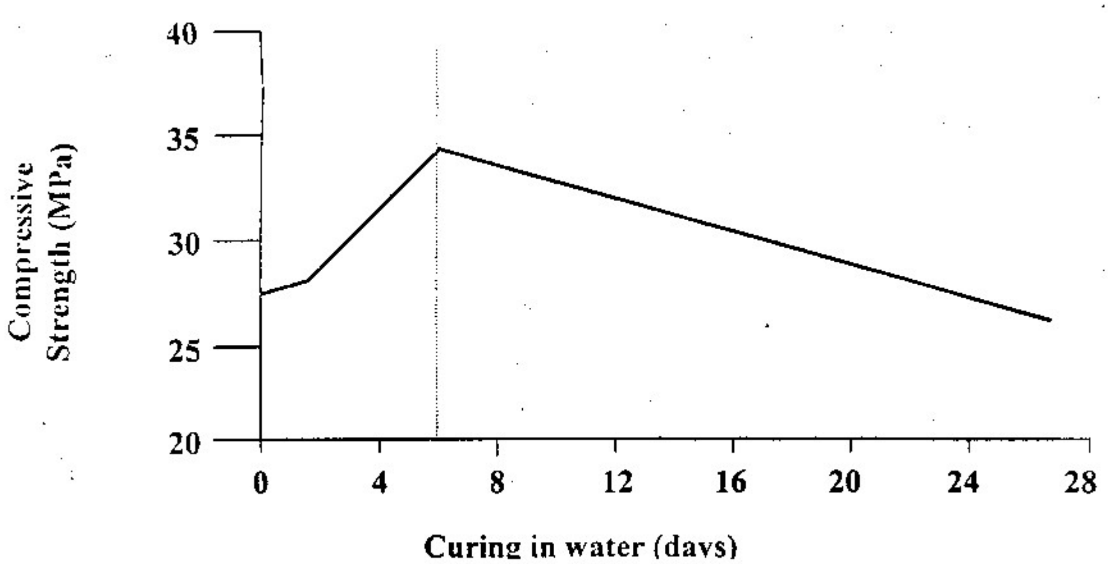

Fig. (2) Effect of curing conditions on compressive strength for modified Polymer Concrete [10]

11. Stress-Strain Relationship for High Strength Steel Cylinder under Uniaxial Compression

In order to obtain complete stress-strain relationship (ascending and descending parts), it is essential to establish the characteristics of the steel cylinder used in this experiment.

The steel tube dimensions are shown in Fig (3). A foil strain gauges were used and fixed in the middle of the outer surface of the steel cylinder, connected with digital strain meter type (TDS-100) and loaded with constant stress rate under compression testing machine type (Forney) with 1818 kN maximum capacity (400,000 lb).

The first specimen was loaded till (0.005) strain reading, then loading was released.

The second test was done for an identical companion steel cylinder but this time it reached a strain of about (0.0179 mm/mm).

These tests were done to find elastic and plastic regions. The test needed for this work is in the region of elastic performance of steel cylinder, which was found up to (0.006) mm/mm. All tests done in this work were made to ultimate strain of (0.0045) in order to be in the safe side and also to use the steel cylinder for all the specimens of this work. Figure (4) iIlustrate the stress-strain relationship for the steel cylinder.

12. Complete Stress-Strain Relationships

Two specimens were investigated for each type of concrete mixes. The same testing machine (ELE compressive testing machine), was used in this test, and concrete specimens dimension were (75×150 mm).

The typical experimental model that was used in this study is shown in Fig.(3).This method was used by Wang and Naaman [13]. This technique is used for the determination of both ascending and descending portions. High strength steel cylinder is used with dimensions as mentioned before. The concrete specimen was placed inside the steel tube with care taken that the top faces of concrete and steel tube should be aligned.

A steel plate was put on the top of both steel and concrete specimens. Foil strain gauges were fixed on the steel cylinder and the load rate was made as recommended by (ASTM-C-469) [12].

Using the following procedure, stress-strain relationship of concrete specimen can be obtained:

1- The concrete specimens (two specimens for each mix) were capped and placed inside the steel cylinder. The steel cylinder should be tested to (0.0045) mm/mm alone in order to know it's elastic behavior.

2- Both specimens are subjected to constant stress rate until reaching 0.0045 mm/mm strain.

3-The set of readings obtained in this test can be used for the determination of stress-strain behavior for concrete specimens.

The strain for each reading was multiplied by the modulus of elasticity of the steel tube to obtain the stress in steel cylinder. Thus,

$$f_s = E_s \times \alpha \qquad \ldots (1)$$

The load on steel cylinder is:

$P_s = f_s \times$ cross sectional area of steel tube

$$P_s = f_s \times A_s \qquad \ldots (2)$$
$$P_{conc} = P_{tot} - P_s \qquad \ldots (3)$$

Where:

f_s: stress in steel cylinder,

E_s: the elastic modulus in each stage for steel cylinder,

: strain measured on steel tube or concrete, α

P_s: load held by steel tube for each reading,

P_{tot}: total load for each stage or reading, and

P_{conc}: load held by concrete specimen for each reading.

Then by using above equation, the load P_{conc}, divided by cross sectional area of specimen gives the stress in concrete.

4- Sets of reading were made to draw a complete stress-strain relationship up to strain of 0.0045.

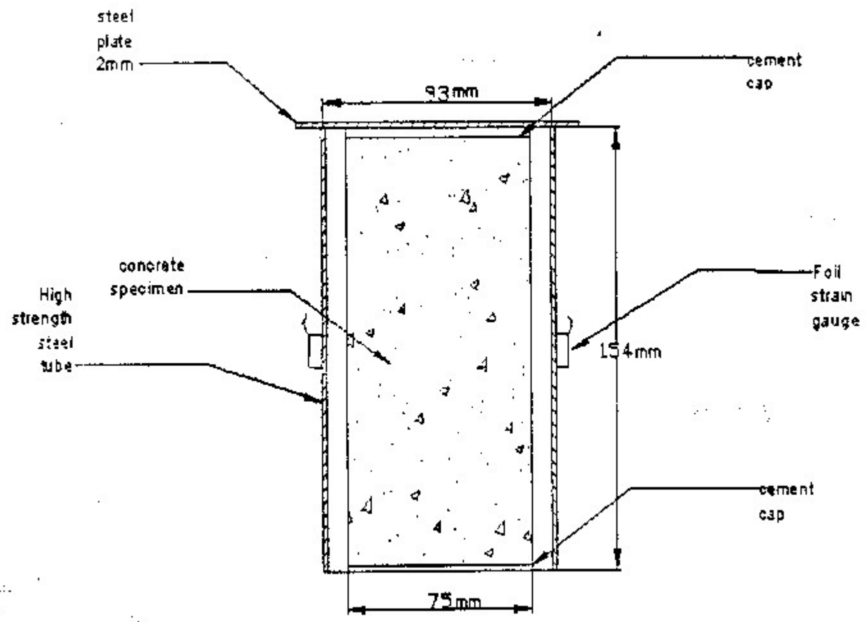

Fig (3) Typical Experimental Model Used in this Study

13. Stress-strain Relationship for No-Fines Polymer Concrete Mixes. Development and Proposed Mathematical Model

13.1 Development of Stress-Strain Relationship

Stress-strain relatioship for reference and polymer concrete mixes were obtained by using simple calculation depends on the performance of high strength steel tube under compression (see Figure (4)). It should be noted that the same stress rate given in (ASTM C-469) specifications was used for both steel tube alone and steel tube with concrete specimen when tested together. For water curing, Figure (5) shows the stress-strain relationship up to (0.0045) strain both ascending and descending portions for (1:7) C/A mix with various p/c ratios.

It can be seen that the (10%) P/C ratio mixes gives less strain for the same strength with comparison to other mixes. Also higher strain peak and higher compressive strength are observed when the P/C ratio increases.

Figures (6, 7 and 8) show the stress-strain relationships for (1:6, 1:5, and 1:4) C/A groups, respectively. For all mixes, the strain value decreases with increasing the P/C ratio for the same stress, for example, for (1:6) C/A mixes, the adding of SBR polymer leads to decrease strain values of reference mixes:- adding 5% polymer/ cement leads to decrease strain values from (0.0010) to about (0.00075) for the same stress (6) MPa.

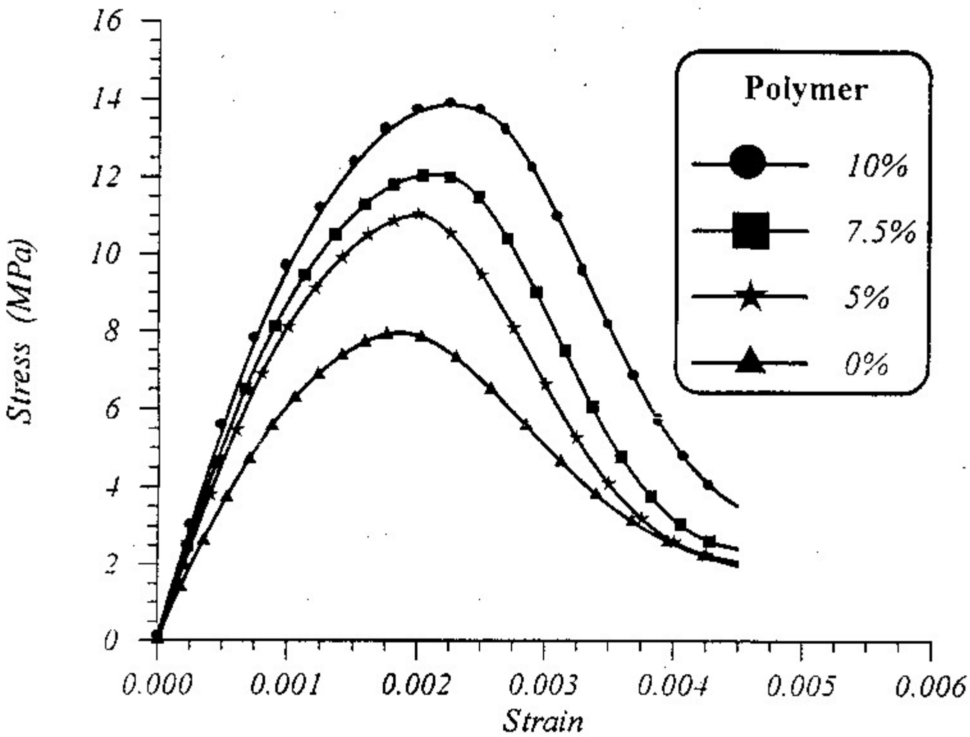

Fig. (5) Stress-Strain Relationship of No-Fines Concrete [1:7 C/A] with Various P/C Ratios

For (1:4) C/A mixes the improving due to P/C increase in both compressive strength and strain decreasing is much less with comparison to lean mixes such as (1:7) C/A mixes because of cement content which is higher in these mixes than (1:7) C/A mixes, and also the voids in (1:7) C/A reference mixes is higher and thus the polymer action to bond aggregates is more effective.

For air curing which is the best way for curing [10], also the same effect was found for decreasing strain values, but the compressive strength here has a higher values, but the compressive strength here has a higher values than water curing, the higher compressive strength leads to higher peak strain(ε_0) for all mixes.

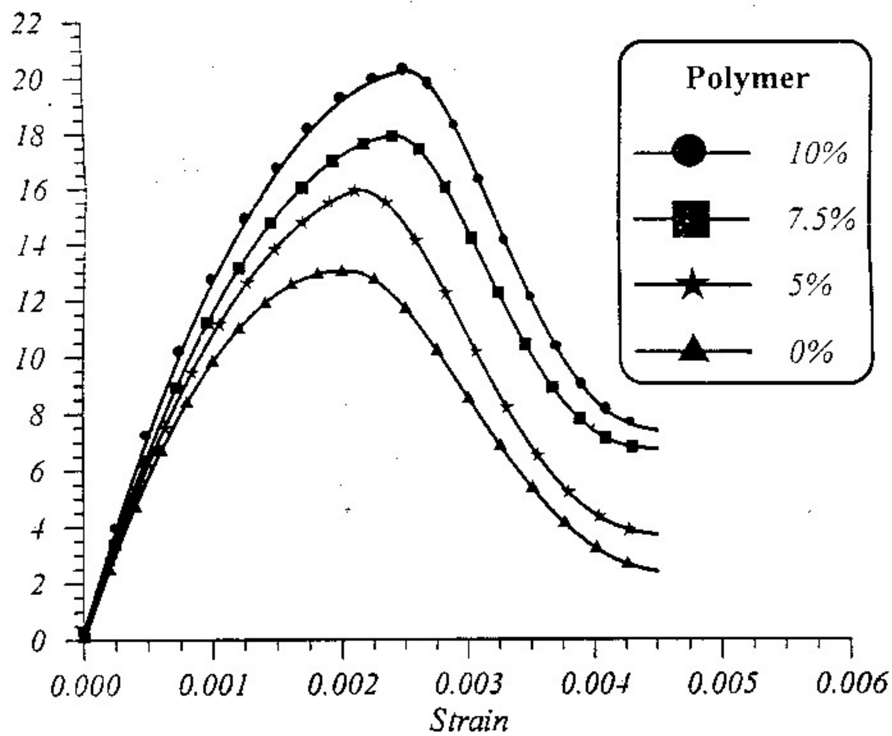

Fig. (6) Stress-Strain Relationship of No- Fines Concrete [1:6 C/A] wih Varios P/C Ratio (water curing)

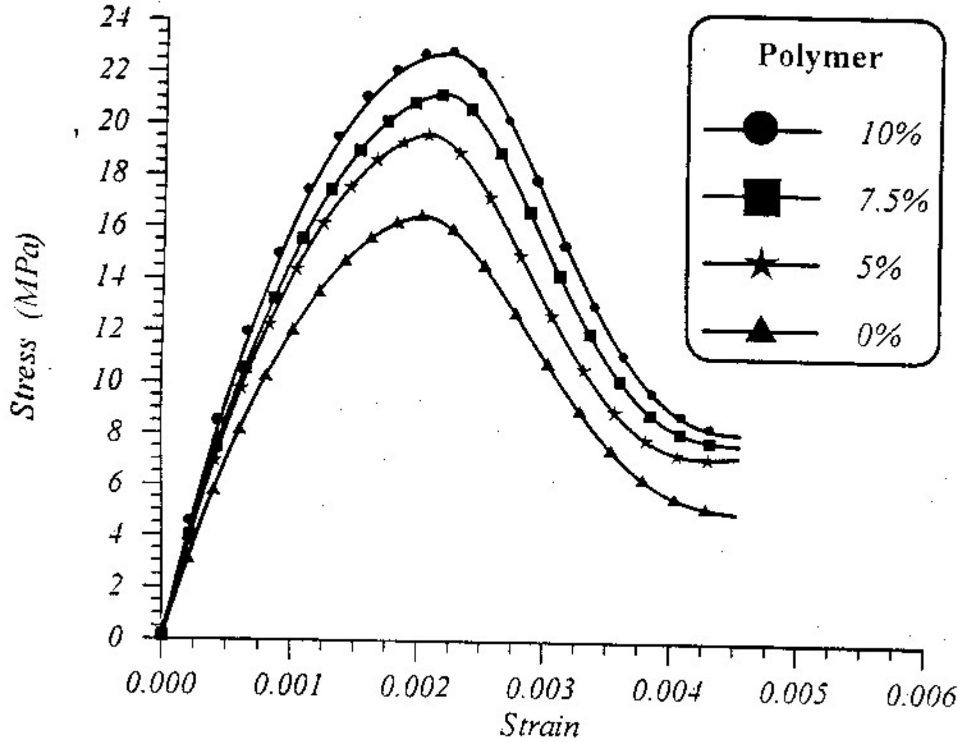

Fig. (7) Stress-Strain Relationship of No-Fines Concrete [1:5 C/A] with Various P/C Ratios (Water curing)

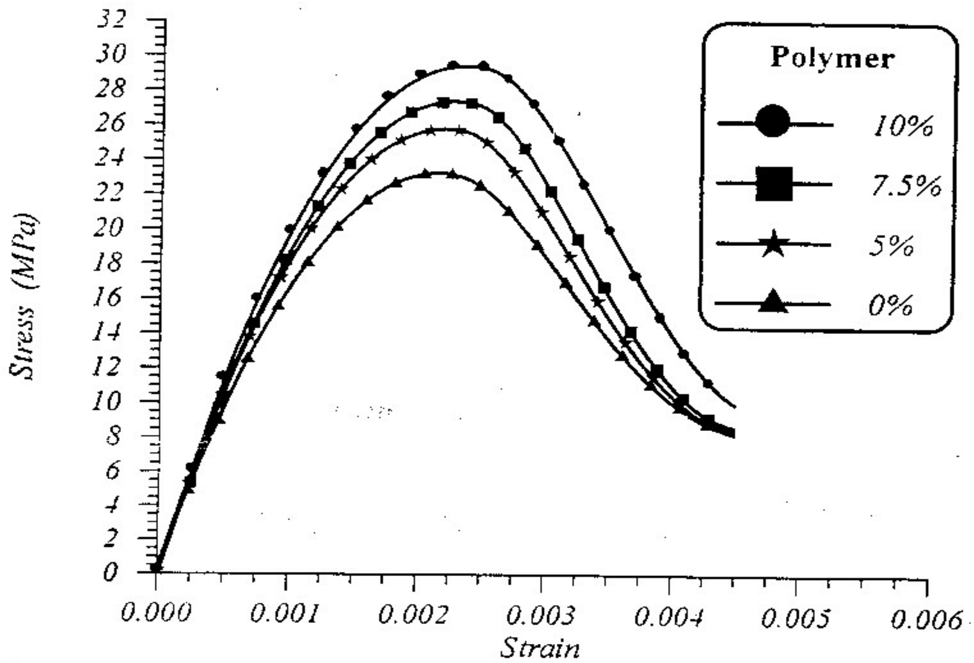

Fig. (8) Stress-Strain Relationship of No-Fines Concrete [1:4 C/A] with Various P/C Ratios (Water curing)

Figures (9) to (12) show the stress-strain behavior for both reference and polymer mixes using air curing. It can be seen that the polymer action on stress-strain relation is in two directions, the first is to decrease strain values and second is in increasing compressive strength values which is higher than water curing case.

Stress-strain relationship is improved by adding polymer, due to the double influence of polymer on stress-strain relationship caused by the polymer films formation of SBR polymer.

Also, polymer latex modification of cement mortar and concrete is governed by both cement hydration and polymer film formation processes, polymer film form by the coalesence of polymer particles in polymer latex. In due course, a co-matrix phase is formed by both cement hydration and polymer film formation processes [(9)].

Also some chemical reactions may take place between the particle surfaces of polymers particles and calcium ions (Ca^{+2}), $Ca(OH)_2$ solid surfaces, or silicate surfaces over the aggregate[(9)].

Also, other factors that cause improvement in the properties for this type of concrete are: first is that the voids in this type is high and some of these voids fill up by polymer and some polymer particles bond with cement hydrates and silicate surfaces of aggregate. And second, it appears that the microcracks in latex-modified mortar and concrete under stress are bridged by the polymer films or membranes formed, which prevent crack propagation. These being simultaneously occurred, strong cement hydrate-aggregate bond is developed.

It should be noted that the area under the curve of stress-strain relationship increase with increasing of P/C ratio for each mix and that means greater energy absorption acquired with the increase of P/C ratio.

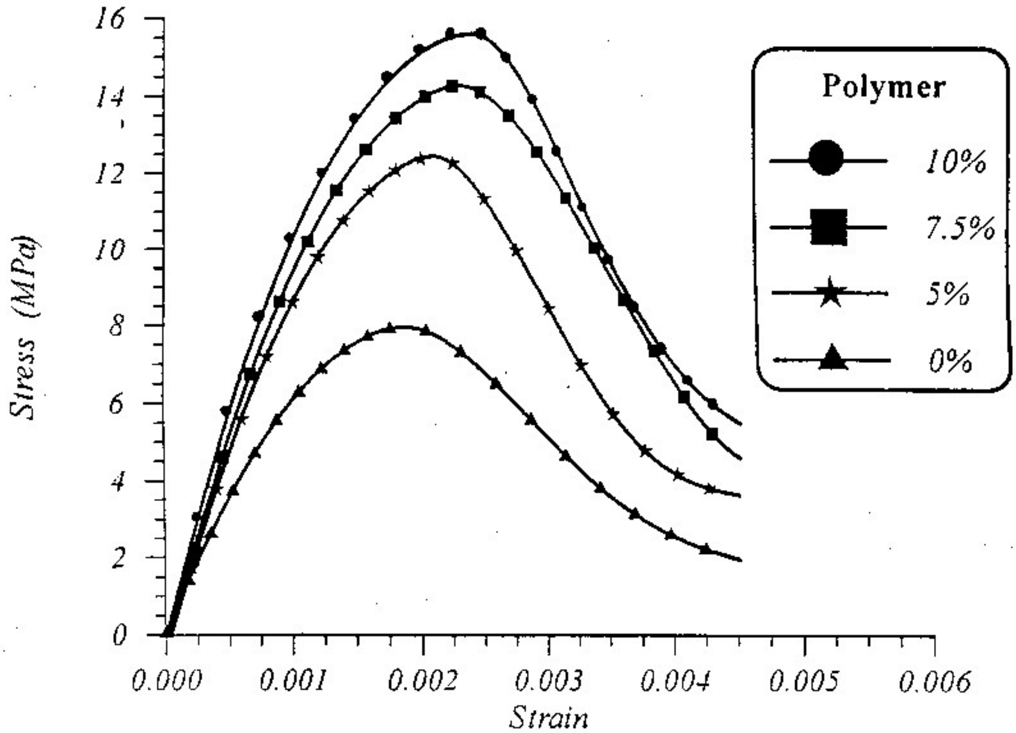

Fig. (9) Stress-Strain Relationship of No-Fines Concrete [1:7 C/A] with Various P/C Ratios (Air curing)

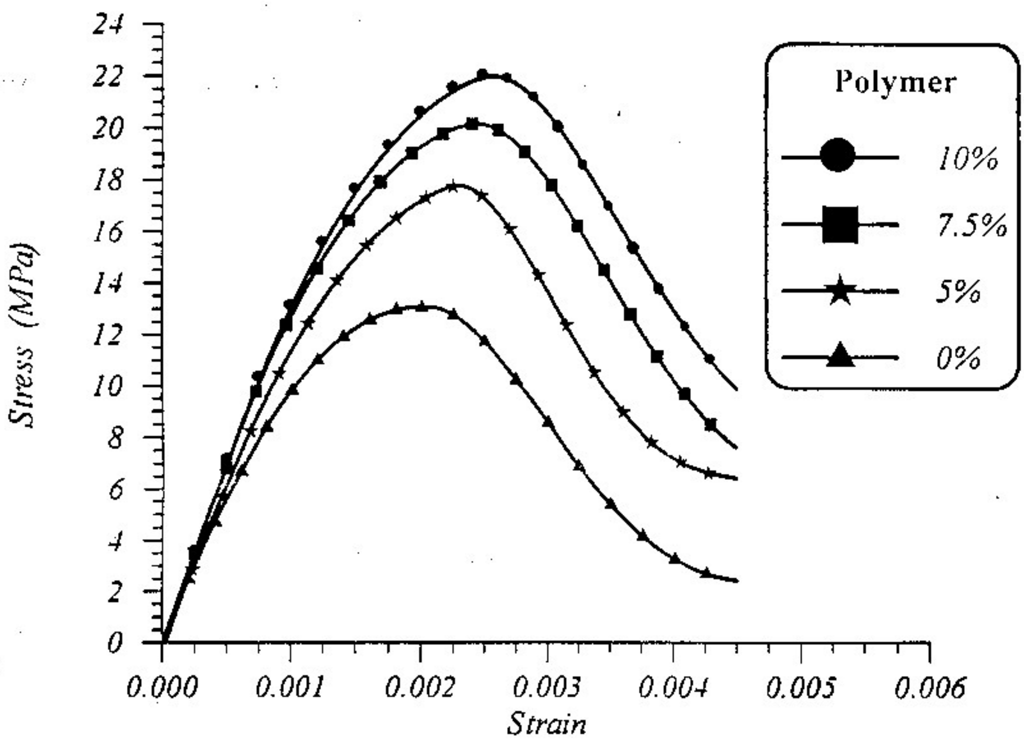

Fig. (10) Stress-Strain Relationship of No-Fines Concrete [1:6 C/A] with Various P/C Ratios (Air curing)

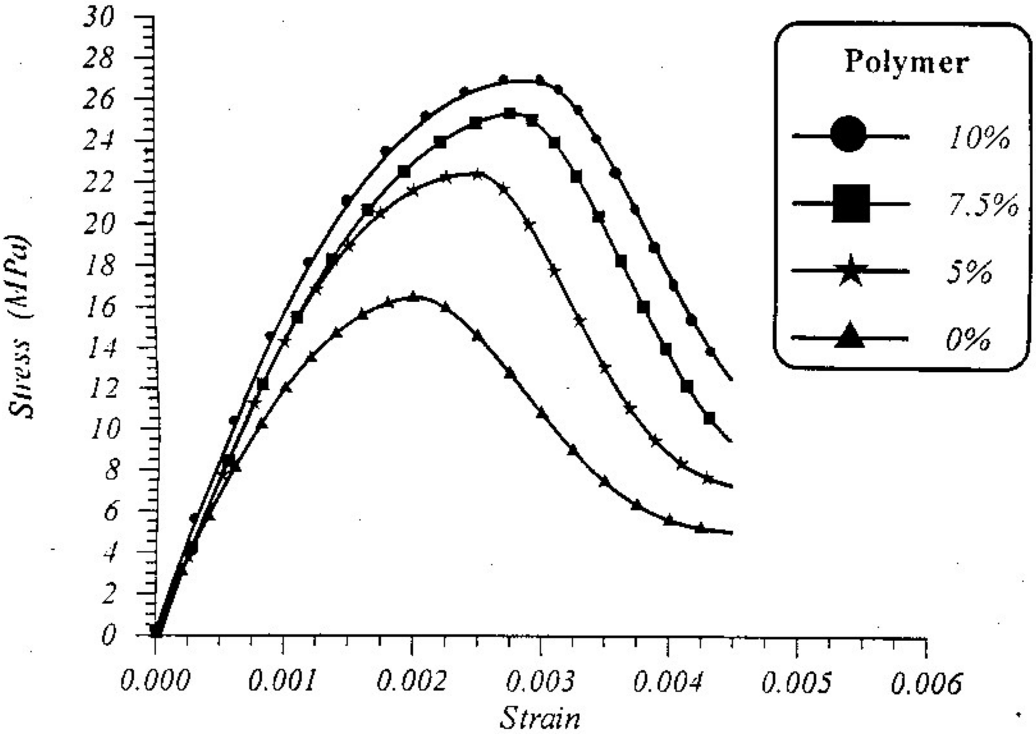

Fig. (11) Stress-Strain Relationship of No-Fines Concrete [1:5 C/A] with Various P/C Ratios (Air curing)

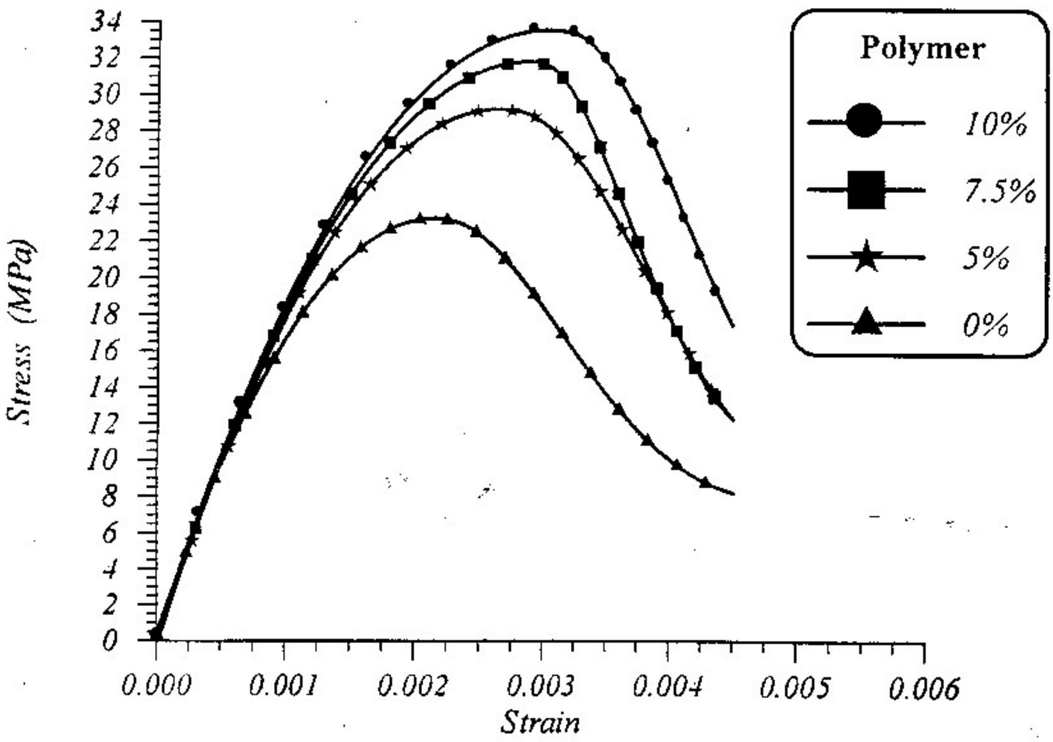

Fig. (12) Stress-Strain Relationship of No-Fines Concrete [1:4 C/A] with Various P/C Ratios (Air curing)

13.2 Proposed Model for Stress-Strain Relationship

The observed stress-strain relationship of this type of concrete has to be expressed analytically.

Most of previous models or equations based only on the properties of ascending part.After a search for a suitable expression by using a computer program, the following general stress-strain relation for both ascending and descending portions were found most acceptable for this type of concrete.

For ascending part, the equation is:

$$F_c = C_0 + C_1\alpha + C_2\alpha^2 \quad \dots (4)$$

For ascending part,

$$F_c = C_0 + C_1\alpha + C_2\alpha^2 + C_3\alpha^3 + C_4\alpha^4 \quad \dots (5)$$

The constants C_0, C_1, C_2, C_3, and C_4 are given in Appendix-A. The equation of ascending part (above) is of the second degree and the three constants of the equation may be found from the properties of the curve itself. The descending part is of the fourth degree and has five constants. Both equations can be used for all mixes, the difference is in the constants which depend on the shape of the curve. Table (4) shows the statistical characteristics of the proposed formula.

Table (4) Statistical Characteristics of the Proposed Stress-Strain Formula for (1:4) C/A Ratio (Air Curing)

P/C %	Part	Standard deviation	Coefficient of variation	Correlation coefficient
0	Asc.	8.2482363	0.5319536	0.961909
	Desc.	6.1941482	0.3994936	0.976495
5	Asc.	9.9788139	0.5092412	0.97532
	Desc.	7.4864489	0.3781989	0.982878
7.5	Asc.	9.659376	0.4271482	0.94857
	Desc.	8.8962539	0.4071512	0.997685
10	Asc.	10.507901	0.4371986	0.944824
	Desc.	8.3673423	0.3321472	0.989745

For other mixes, corelation coefficients are essentially in the same range of Table (4)

14. Conclusions

1. In spite of the improvement in properties in the mixes of no-fines concrete due to using SBR polymer in (1:7) C/A mixes, both reference and polymer mixes, can not be used in structural members. This is true for (1:6) C/A group except that with (10%) P/C, the reason is the Iow compressive strength for this mixes (less than 17 Mpa), and also low modulus of elasticity which is found much less than (20000) MPa.
2. Both (1:4) and (1:5) C/A of polymer no-fines concrete can be used for structural purposes and also for (1:6) C/A with (10%)P/C ratio.
3. The proposed model for no-fines polymer concrete has a general form for all mixes and for both curing conditions. The constants change from mix to mix and each set of constant changes to fit the shape of stress-strain relationship.

4. Air curing was found beneficial for no-fines polymer concrete. The strength values for air cured specimens are higher than that for water cured ones. Cylinder Strength values range from 8 to 34 MPa for the whole specimens.

15. References

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Appendix A: Stress-Strain Model Constants.

Table (A.1): Model constants for C/A = 1/5, air curing condition

p/c %	type	C_0	C_1	C_2	C_3	C_4
0	Asc.	0	15591.3	$-3.70199\times10^{+6}$		
	Desc.	-82.9427	134084	$-6.2923\times10^{+7}$	$1.19935\times10^{+10}$	$-8.14811\times10^{+11}$
5	Asc.	0	18704.3	$-3.79301\times10^{+6}$		
	Desc.	-352.528	436583	$-1.82052\times10^{+8}$	$3.21063\times10^{+10}$	$-2.058\times10^{+12}$
7.5	Asc.	0	17795.1	$-3.06327\times10^{+6}$		
	Desc.	-298.24	325864	$-1.15399\times10^{+8}$	$1.67916\times10^{+10}$	$-8.5826\times10^{+12}$
10	Asc.	0	18794.4	$-3.29822\times10^{+6}$		
	Desc.	-401.885	415980	$-1.43969\times10^{+8}$	$2.09429\times10^{+10}$	$-1.09877\times10^{+12}$

Table (A.2): Model constants for C/A = 1/6, air curing condition

p/c %	type	C_0	C_1	C_2	C_3	C_4
0	Asc.	0	13070	$-3.26667\times10^{+6}$		
	Desc.	-65.193	102214	$-461231\times10^{+7}$	$8.35772\times10^{+9}$	$-5.36444\times10^{+11}$
5	Asc.	0	14486.6	$-2.87636\times10^{+6}$		
	Desc.	-177.731	241862	$-1.06188\times10^{+8}$	$1.9485\times10^{+10}$	$-1.29137\times10^{+12}$
7.5	Asc.	0	16052.4	$-3.15957\times10^{+6}$		
	Desc.	-97.7642	128868	$-4.84707\times10^{+7}$	$7.24937\times10^{+9}$	$-3.74636\times10^{+11}$
10	Asc.	0	16480.7	$-3.01158\times10^{+6}$		
	Desc.	-131.4	164591	$-6.19553\times10^{+7}$	$9.59662\times10^{+9}$	$-5.34824\times10^{+11}$

Table (A.3): Model constant for C/A = 1/7, air curing condition

p/c %	type	C_0	C_1	C_2	C_3	C_4
0	Asc.	0	8039.61	$-2.02338\times10^{+6}$		
	Desc.	-20.1901	39762.4	$-1.91941\times10^{+7}$	$3.65783\times10^{+9}$	$-2.47339\times10^{+11}$
5	Asc.	0	11660.9	$-2.60751\times10^{+6}$		
	Desc.	-56.7573	89565.6	$-3.99236\times10^{+8}$	$7.09469\times10^{+9}$	$-4.40294\times10^{+11}$
7.5	Asc.	0	12256.8	$-2.55455\times10^{+6}$		
	Desc.	-37.0167	55639.7	$-1.97362\times10^{+7}$	$2.46622\times10^{+9}$	$-8.25168\times10^{+10}$
10	Asc.	0	12935.5	$-2.67067\times10^{+6}$		
	Desc.	-158.291	204132	$-8.52358\times10^{+7}$	$1.4929\times10^{+10}$	$-9.49087\times10^{+11}$

Table (A.4): Model constant for C/A = 1/4, water curing condition

p/c %	type	C_0	C_1	C_2	C_3	C_4
0	Asc.	0	21256.7	$-4.93011\times10^{+6}$		
	Desc.	-119.024	173710	$-7.39378\times10^{+7}$	$1.28124\times10^{+10}$	$-7.91947\times10^{+11}$
5	Asc.	0	23289.9	$-5.30269\times10^{+6}$		
	Desc.	-166.171	229780	$-9.6177\times10^{+7}$	$1.64605\times10^{+10}$	$-1.00435\times10^{+12}$
7.5	Asc.	0	24239.2	$-5.329\times10^{+6}$		
	Desc.	-219.591	286797	$-1.1686\times10^{+8}$	$1.95577\times10^{+10}$	$-1.1661\times10^{+12}$
10	Asc.	0	24905.5	$-5.2969\times10^{+6}$		
	Desc.	-174.779	222146	$-8.34853\times10^{+7}$	$1.2517\times10^{+10}$	$-6.51561\times10^{+11}$

Table (A.5): Model constants for C/A = 1/ 5, water curing condition

p/c %	type	C_0	C_1	C_2	C_3	C_4
0	Asc.	0	15591.3	$-3.70199\times10^{+6}$		
	Desc.	-82.9427	134084	$-6.2923\times10^{+7}$	$1.19935\times10^{+10}$	$-8.14811\times10^{+11}$
5	Asc.	0	18082.3	$-4.19403\times10^{+6}$		
	Desc.	-123.623	192054	$-9.01476\times10^{+7}$	$1.73414\times10^{+10}$	$-1.19037\times10^{+12}$
7.5	Asc.	0	18748	$-4.16861\times10^{+6}$		
	Desc.	-180.355	258857	$-1.17454\times10^{+8}$	$2.21332\times10^{+10}$	$-1.50034\times10^{+12}$
10	Asc.	0	20615.8	$-4.67879\times10^{+6}$		
	Desc.	-194.13	271935	$-1.20384\times10^{+7}$	$2.21101\times10^{+10}$	$-1.45932\times10^{+11}$

Table (A.6): Model constants for C/A = 1/6, water curing condition

p/c %	type	C_0	C_1	C_2	C_3	C_4
0	Asc.	0	13070	$-3.26667\times10^{+6}$		
	Desc.	-65.193	102214	$-461231\times10^{+7}$	$8.35772\times10^{+9}$	$-5.36444\times10^{+11}$
5	Asc.	0	13384.7	$-2.78997\times10^{+6}$		
	Desc.	-117.959	172503	$-7.77881\times10^{+7}$	$1.43814\times10^{+10}$	$-9.50814\times10^{+11}$
7.5	Asc.	0	14238.3	$-2.83831\times10^{+6}$		
	Desc.	-259.068	331327	$-1.41683\times10^{+8}$	$2.55603\times10^{+10}$	$-1.67109\times10^{+12}$
10	Asc.	0	15316.3	$-2.92214\times10^{+6}$		
	Desc.	-351.497	431342	$-1.79607\times10^{+8}$	$3.17049\times10^{+10}$	$-2.03434\times10^{+12}$