Modeling the Shear Strength of Reinforced Aerated Concrete Slabs via Support Vector Regression

Ahmet Emin Kurtoglu*‡, Derya Bakbak**

*Department of Civil Engineering, Istanbul Gelisim University, 34315, Avcılar, Istanbul, Turkey

**The Grand National Assembly of Turkey (TBMM), 06534, Çankaya, Ankara, Turkey

(aekurtoglu@gelisim.edu.tr, derya.bakbak@tbmm.gov.tr)

‡ Corresponding Author; Ahmet Emin Kurtoglu, Istanbul Gelisim University, 34315, Avcılar, Istanbul, Turkey, Tel: +90 212 422 7000,

aekurtoglu@gelisim.edu.tr

Received: 02.02.2019 Accepted:02.03.2019

Abstract- Autoclaved aerated concrete (AAC) attracts attention as it provides superior material characteristics such as high thermal insulation and environmentally friendly properties. Apart from non-structural applications, AAC is being considered as a structural material thanks to its characteristics such as lighter weight compared to normal concrete, resulting in lower design costs. This study focuses on the feasibility of support vector regression (SVR) in predicting the shear resistance of reinforced AAC slabs. An experimental dataset with 271 data points extracted from eleven sources is used to develop models. Based on random selection, the dataset is divided into two portions, 75% for model development and 25% for testing the validity of the model. Two SVR model types (epsilon and *Nu*) and four kernel functions (linear, polynomial, sigmoid and radial basis) are used for model development and the results of each model and kernel type is presented in terms of correlation coefficient (R^2) and mean squared error (*MSE*). Results show that epsilon model type with radial basis function yields the best SVR model.

Keywords Autoclaved aerated concrete, reinforced concrete slab, shear strength, support vector regression, modelling.

1. Introduction

Autoclaved aerated concrete (AAC) is made of cement or lime mortar which contains air voids entrapped in the matrix by means of an expansion agent. AAC has been used in the construction industry for non-structural and structural applications since mid-1920s. The main property of AAC is high porosity, i.e., up to above 70% of the volume contains air voids, resulting in lower density which minimizes the design cost [1]. AAC is considered to be environmentally friendly material as it reduces 70% and 40% energy per material volume as compared to normal concrete and bricks, respectively. It also provides high thermal insulation [2, 3].

Production of AAC panel elements with reinforcement can offer an alternative for low-rise precast construction. 60% of new building constructions in Europe are built with different types of AAC elements [4]. In the housing industry in China, reinforced AAC materials for exterior walls are preferred to other materials [4].

Shear resistance of reinforced normal concrete or AAC slabs without shear reinforcement is a complex phenomenon. It is known that the shear resistance depends not only on the concrete properties but also on the shear-span-to-depth (a/d) ratio as well as the presence of tensile reinforcement (Fig. 1). Aroni and Cividini (1989) proposed a formulation (Eq. 1a, Eq.1b) for the shear strength of reinforced AAC slabs with a modification to the formulation available for normal concrete slabs [5]. Fig. 2 shows a typical shear resistance test setup of reinforced AAC slab.

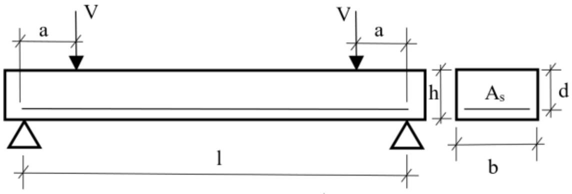

Fig. 1. Schematic of typical test setup

$$\tau_u = 0.035 f_c + 1.163\rho(d/a) - 0.053 \quad \text{within the normal range} \tag{1a}$$

$$\tau_u = 0.039 f_c + 0.82\rho(d/a) - 0.075 \quad \text{outside the normal range} \tag{1b}$$

where τ_u is the ultimate shear stress in MPa (τ_u = V_u/bd), f_c is the compressive strength of AAC in MPa, ρ is reinforcement ratio (*100A$_s$/bd*), *d* is the effective depth in mm, a is the shear span in mm.

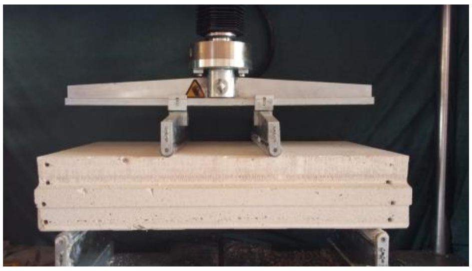

Fig. 2. Test setup

In this study, a novel machine learning based regression method, namely support vector regression, is implemented to produce predictive models for the shear resistance of reinforced AAC slabs.

2. Experimental Data

The experimental data consist of 271 data points extracted from previously published papers [6-15]. Table 1 summarizes the origins and product types for the tests. All data points were included in the modeling process. Data inputs are *fc* (compressive strength), *d/a* (span-to-depth ratio) and ρ (reinforcement ratio), the output is τ *(ultimate shear stress, V/bd).* Table 2 presents the statistical variations of input and output parameters. Some specimens contained compression reinforcement consisting of two or three bar. Possible contributions of these bars in shear strength have been neglected.

Table 1 References and types of test product

Series No.	Reference	Product type
1	Bernon [14] (France)	Siporex
2	Blaschke [13] (Germany)	Ytong
3	Briesemann [12] (Germany)	Hebel
4	Cividini [11] (Yugoslavia)	Siporex, Ytong
5	Dalby [10] (Sweden)	Siporex
6	Edgren [10] (Sweden)	Siporex
7	Kanoh ’66 [9] (Japan)	Siporex
8	Kanoh ’69 [8] (Japan)	Hebel
9	Matsamura [7] (Japan)	ALC
10	Newarthill [6] (UK)	Siporex
11	Regan [15] (UK)	Durox

Table 2 Statistics of experimental data

	fc (MPa)	*d/a*	ρ	τ_u *(Mpa)*
Minimum	2.3	0.08	0.12	0.107
Maximum	7.8	0.766	1.349	0.836
Mean	3.78	0.24	0.41	0.24
Standard deviation	1.31	0.16	0.26	0.14
Coeff. of variation	0.35	0.66	0.62	0.56

3. Support vector machines

Support vector machines (SVMs) were first identified by Boser et al. (1992) is an artificial intelligence learning technique developed to solve the classification problem [16]. However, researchers began using SVM to solve regression problems, and this method was named support vector regression (SVR).

SVM has performed well in many applications such as text analysis, face recognition, image processing and bioinformatics, as well as a strong digital basis in statistical learning theory. This shows that SVM is one of the most modern methods of machine learning and data mining, along with other methods such as neural networks and fuzzy systems [17].

2.1. Support vector regression (SVR)

In SVR, the main purpose is to obtain a function whose actual output value is estimated with the maximum deviation of epsilon and to get two parallel planes for this function. The distance between these planes must be minimized. [18].

For the training data set presented in SVR, the main objective is to find a function with the difference from specific target. At the same time, the function should be flattest with errors less than a certain amount without excess deviation [18]. The (linear) ε-insensitive loss function *L(x, y, f)* is described as

$$L^{\varepsilon}(x,y,f)=|y-f(x)|_{\varepsilon}=\begin{cases}0 & if\,|y-f(x)|\le\varepsilon\\ |y-f(x)|-\varepsilon & otherwise\end{cases} \quad (3a)$$

where f is a real-valued function on a x and the quadratic ε-insensitive loss is defined by

$$L_2^{\varepsilon}(x,y,f)=|y-f(x)|_{\varepsilon}^2 \quad (3b)$$

Fig. 3 demonstrates the linear and quadratic ε-insensitive loss function for zero and non-zero ε.

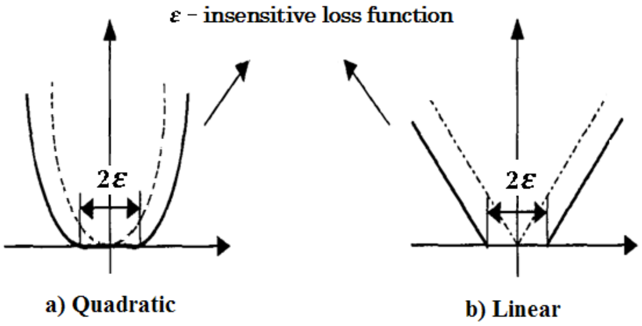

Fig. 3 The form of linear and quadratic ε-insensitive loss function for zero and non-zero ε.

The loss function defines the accuracy performance. Performing linear regression in the high-dimension feature space by the use of ε-insensitive loss function, SVM attempts to reduce the model complexity by performing the minimization of $\|\omega\|^2$. By introducing slack variables $\xi_j, \xi_i^* \, i=1,..n$

$$L(y,f(x,\omega))=|y-f(x)|_{\varepsilon}^2$$
$$L_2^{\varepsilon}(x,y,f)=|y-f(x)|_{\varepsilon}^2 \quad (3c)$$

to determine the deviation of training data outside ε -zone. Following formulation is implemented for the minimization of SVM regression:

$$\frac{1}{2}\|\omega\|^2+c\sum_{i=1}^{n}(\xi_i+\xi_i^*) \text{ subject to } \xi_j,\xi_i^* \, i=1,..n \quad (3d)$$

$$\xi_j,\xi_i^* \, i=1,..n \quad (3e)$$

The solution of this optimization problem can be found by transforming it into the dual problem:

$$f(x)=\sum_{i=1}^{n_{sv}}(\alpha_j-\alpha_i^*)K(x_j,x)+b \text{ subject to}$$
$$0\le\alpha_i^*\le C, 0\le\alpha_j\le C \quad (3f)$$

where n_{sv} is the number of support vectors (SVs), a_i^* and a_j are the Lagrange multipliers and $K(x_j, x)$ is a kernel function and b is the bias term. The generalization of SVM depends on the appropriate settings of meta-C, ε, and kernel parameters. Available software applications generally have the option for manual specification of meta-parameters [19].

The model complexity and the degree, to which deviations larger than ε are tolerated, are controlled by a parameter C controls in optimization formulation. Parameter ε describes the width of ε-insensitive zone, which is utilized to fit the training data. Value of ε can affect the number of support vectors used to form the regression function. On the other hand, greater ε-insensitive values cause more 'flat' predictions. Although in different ways, both C and ε values affect model complexity (flatness) [19].

Several kernel functions are used in machine learning. Four functions used in this study are:

Linear function:

$$K(x_i,x)=x_i x \quad (4a)$$

Polynomial function:

$$K(x_i,x)=(x_i(x+1))^d \quad (4b)$$

Radial-based function:

$$K(x_i,x)=\exp\left[-\frac{(x_i-x)(x_i-x)}{2\sigma^2}\right] \quad (4c)$$

Sigmoid function:

$$K(x_i,x)=\tanh(x_i(x+1)) \quad (4d)$$

where x_i and x, are the training and test inputs, respectively, σ is the Gaussian kernel function and d is the polynomial degree of kernel function.

4. Model Development

Experimental data (three inputs and one output) is divided into two portions, i.e., 75% of the data is used as model training set, 25% is used for testing the validity of the model. SVR models are developed by optimizing the meta parameters C and ε or *Nu*, by performing a grid search along a pre-specified range. The model with best correlation coefficient (R^2) is selected for each model type and kernel function. Correlation coefficient (R^2) measure the relationship between predicted and experimental data, in which $R^2 = 1$ means significant correlation and $R^2 = 0$ means no correlation. Eq. 5.1 and Eq. 5.2 are used for calculating correlation coefficient (R^2) and mean squared error (*MSE*), respectively. Fig. 4 shows the correlation coefficient (R^2) values for eight SVR models developed using two model types and four kernel functions. SVR models developed with Radial Basis kernel appear to yield better fitting results as compared to other kernel types. Epsilon model type with radial basis kernel gives the best correlation coefficient (total set: 0.936, training set: 0.945, testing set: 0.901).

$$R^2 = 1 - \left(\frac{\sum_{i=1}^{N} (o_i - t_i)^2}{\sum_{i=1}^{N} (o_i - o')^2} \right) \tag{5.1}$$

$$MSE = \frac{\sum_{i=1}^{N} (o_i - t_i)^2}{N} \tag{5.2}$$

where o_i is the experimental value of *ith* data, t_i is the predicted value of *ith* data, N is the number of data used for training and testing of SVR models.

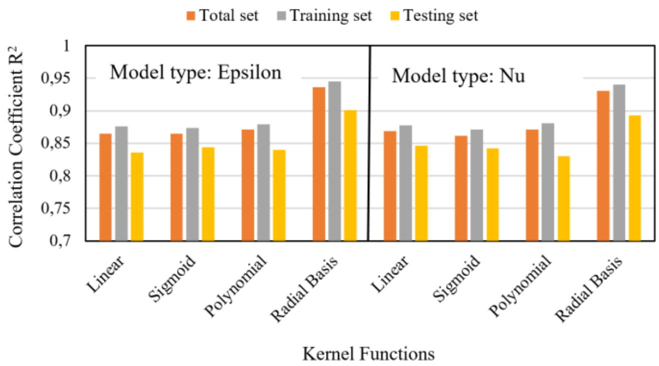

Fig. 4 Correlation coefficient of SVR models

Fig. 5 shows mean squared error (*MSE*) values calculated for each SVR model type, using Eq. 5.2. SVR models produced with sigmoid kernel appear to yield significantly large errors while models with radial basis kernel produces less *MSE*. Table A.1. lists the support vectors generated by the SVR-Eps-Rad model.

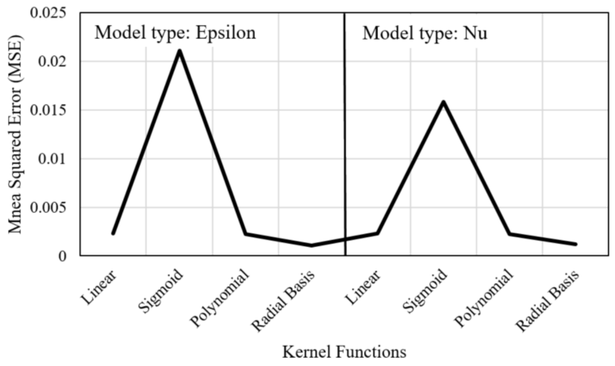

Fig. 5 Mean squared error of SVR models

Fig. 6 compares the experimental and estimated values of SVR-Eps-Rad model both for training and testing datasets.

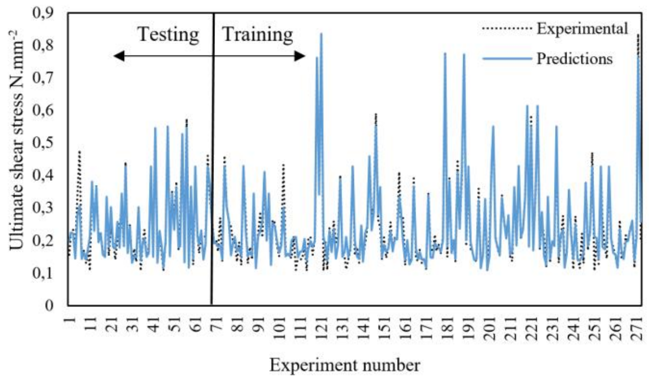

Fig. 6 Experimental data versus predictions of SVR-Eps-Rad model

According to [20], if the correlation coefficient R^2 is greater than 0.8 and the error values are at a desirable range, there is a strong correlation between predicted and real values. Regarding Fig. 7, proposed SVR-Eps-Rad model has a R^2 value of 0.931 for whole set and the error is acceptable, as seen in Fig. 5.

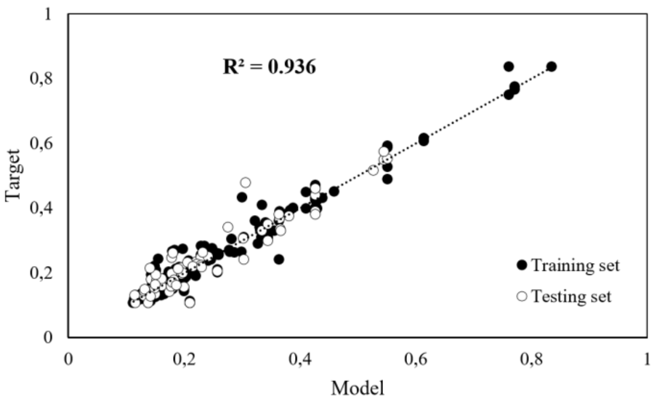

Fig. 7 Comparison of predicted values and experimental values of Ultimate Shear Stress (MPa)

5. Conclusion

This study analyzes the feasibility to use support vector regression method to propose a predictive model for ultimate shear stress of reinforced aerated concrete. Different model types (epsilon and *Nu*) and kernel function types (linear, sigmoid, polynomial, radial basis) are used for model development to analyze the feasibility. An experimental dataset with 271 data points is implemented to develop models. Dataset is divided into two portions, 75% for model development and 25% is for testing the validity of the model, based on random selection. Each model is analyzed statistically to determine the prediction performance. For this, mean squared error (*MSE*) and correlation coefficient (R^2) are used. For epsilon model type, R^2 values for total set are 0.865, 0.865, 0.871 and 0.936 for linear, sigmoid, polynomial and radial basis kernel types, respectively. On the other hand, for *Nu* model type, R^2 values for total set are 0.869, 0.862, 0.871 and 0.931 for linear, sigmoid, polynomial and radial basis kernel types, respectively. Hence, SVR model based on epsilon model type and radial basis kernel function gives the best correlation coefficient values. Sigmoid kernel based models yield largest *MSE* values while radial basis kernels produce less *MSE*. Finally, the results confirm that support vector regression (SVR) method has the advantage to be easily applied and yield reasonably accurate prediction performance.

References

[1] A. Thongtha, S. Maneewan, C. Punlek, and Y. Ungkoon, "Investigation of the compressive strength, time lags and decrement factors of AAC-lightweight concrete containing sugar sediment waste", Energy and Buildings, vol. 84, No., pp. 516-525, 2014.

[2] X. Qu and X. Zhao, "Previous and present investigations on the components, microstructure and main properties of autoclaved aerated concrete–A review", Construction and Building Materials, vol. 135, pp. 505-516, 2017.

[3] A. Bonakdar, F. Babbitt, and B. Mobasher, "Physical and mechanical characterization of fiber-reinforced aerated concrete (FRAC)", Cement and Concrete Composites, vol. 38, pp. 82-91, 2013.

[4] A. Taghipour, E. Canbay, B. Binici, A. Aldemir, U. Uzgan, and Z. Eryurtlu, "Seismic behavior of reinforced autoclaved aerated concrete wall panels", ce/papers, vol. 2, No. 4, pp. 259-265, 2018.

[5] S. Aroni and B. Cividini, "Shear strength of reinforced aerated concrete slabs", Materials and Structures, vol. 22, No. 6, pp. 443-449, 1989.

[6] N. Edgren, "Shear tests on Siporex slabs (Newarthill Factory, UK)'", unpublished report (Internationella Siporex AB, Central Laboratory, 1981–82).

[7] A. Matsumura, "Shear strength and behavior of reinforced autoclaved lightweight cellular concrete members", Trans. Architect. Inst. Jpn, vol. 343, pp. 13-23, 1984.

[8] Y. Kanoh, "Report of Hebel research'", unpublished report (Meiji University, 1969).

[9] Y. Kanoh, "Shear strength of the reinforced autoclaved lightweight concrete one-way slabs'", Proceedings of Research Papers of the Faculty of Engineering, Meiji University, vol., No. 21, 1966.

[10] N. Edgren, "Shear tests on Siporex slabs (Dalby Factory, Sweden)'", unpublished report (Internationella Siporex AB, Central Laboratory, 1979).

[11] B. Cividini, "Ispitivanje granicne nosivosti armiranih ploca od plinobetona (Investigation of bearing capacity of reinforced aerated concrete slabs)", Proceedings of 17th JUDIMK Congress, Sarajevo, October, pp. 19-41, 1982.

[12] D. Briesemann, Die schubtragfähigkeit bewehrter platten und balken aus dampfgehärtetem gasbeton anch versuchen, Ernst, 1980.

[13] R. Blaschke, "Shear load behaviour of AAC reinforced units of high compressive strength (GB 6.6)'", unpublished report (Ytong Research Laboratory, Schrobenhausen, 1988), 1988.

[14] N. Edgren, "Shear tests on Siporex slabs (Bernon Factory, France)'", unpublished report (Internationella Siporex AB, Central Laboratory, 1979–80).

[15] P. Regan, "Shear in reinforced aerated concrete", International Journal of Cement Composites and Lightweight Concrete, vol. 1, No. 2, pp. 47-61, 1979.

[16] B.E. Boser, I.M. Guyon, and V.N. Vapnik, "A training algorithm for optimal margin classifiers", Proceedings of the fifth annual workshop on Computational learning theory, pp. 144-152, 1992.

[17] L. Wang, Support Vector Machines: theory and applications, vol. 177, Springer, 2005

[18] N. Chen, W. Lu, J. Yang, and G. Li, Support vector machine in chemistry, vol. 11, World Scientific, 2004

[19] V. Cherkassky and Y. Ma, Selection of meta-parameters for support vector regression, Artificial Neural Networks—ICANN 2002, Springer, 2002, 687-693.

[20] G.N. Smith, "Probability and statistics in civil engineering", Collins Professional and Technical Books, vol. 244, No., 1986.

Appendix

Table A.1. Support vectors for SVR-Eps-Rad model

Index	Coefficient	Support Vector (normalized)
1	88888.9	-0.745455, -0.892128, -0.674532
2	88888.9	-0.62, -0.41691, -0.158666
3	88888.9	-0.527273, -0.833819, -0.563873
4	-83099.1	-1, -0.177843, -1
5	-88888.9	-0.625455, -0.810496, -0.389748
6	-79853.3	-0.745455, -0.77551, -0.558991
7	88745.5	-0.62, 0.950437, 1
8	88888.9	-0.610909, -0.909621, -0.554109
9	-88888.9	-0.659273, -0.944606, -0.485761
10	-88888.9	-0.745455, -0.723032, -0.785191
11	67164.1	-0.8, -0.6793, -0.536208
12	-88888.9	1, 0.48105, -0.728234
13	-88888.9	-0.549091, -0.795918, -0.607811
14	88888.9	-0.445091, -0.609329, -0.103336
15	15268.4	-0.659273, -0.880466, -0.218877
16	-82948.9	0.272727, -0.653061, -0.853539
17	-88888.9	-0.527273, -0.201166, -1
18	88888.9	-0.527273, -0.58309, -0.685924
19	-88888.9	0.272727, -0.0612245, -1
20	88888.9	-0.527273, -0.921283, -0.661513
21	88888.9	-0.527273, -0.994169, 0.0903173
22	-20775.4	-0.62, -0.058309, 1
23	-88888.9	-0.445091, -0.623907, -0.0707893
24	-88888.9	-0.781818, -0.892128, -0.602929
25	88888.9	-0.927273, -0.708455, -0.567128
26	-88888.9	-0.781818, -0.825073, -0.793328
27	-88888.9	-1, -0.723032, -0.609439
28	-88888.9	-0.781818, -0.725948, -0.79821
29	64448.1	-0.563636, -0.102041, -0.18633
30	88888.9	-0.527273, -0.83965, -0.552482
31	-88888.9	-0.781818, -0.825073, -0.593165
32	-88888.9	-0.625455, -0.609329, -0.389748
33	88888.9	-0.195273, -0.883382, -0.562246
34	-56839.3	-0.236364, -0.548105, -0.910496
35	88888.9	-0.610909, -0.650146, -0.585028
36	-88888.9	-0.527273, -0.994169, 0.0903173
37	88888.9	-0.527273, -0.714286, -0.768918
38	88888.9	-0.527273, -0.810496, -0.66965
39	-88888.9	-0.549091, -0.376093, -0.607811
40	-88888.9	1, 0.48105, -0.728234
41	88888.9	-1, -0.183673, -1
42	-88888.9	-0.563636, -0.568513, -0.121237
43	88888.9	-0.2, -0.440233, -0.973963
44	-88888.9	-0.236364, -0.696793, -0.495525
45	-88888.9	-0.549091, -0.795918, -0.607811
46	-88888.9	-0.745455, -0.883382, -0.685924
47	-88888.9	-0.625455, -0.915452, -0.389748
48	-88888.9	-0.549091, -0.795918, -0.607811
49	15537.1	-0.236364, -0.358601, -0.104963
50	-88888.9	-0.781818, -0.810496, -0.710334
51	-88888.9	-0.927273, -0.708455, -0.542718
52	-88888.9	-1, -0.728863, -0.853539
53	-88888.9	-0.549091, -0.376093, -0.607811
54	-88888.9	-0.527273, -0.632653, -0.853539
55	-88888.9	-0.625455, -0.609329, -0.389748
56	88888.9	1, 0.300292, -0.728234
57	88888.9	-0.8, -0.763848, -0.542718
58	-88888.9	-0.527273, -0.623907, -0.853539
59	-88888.9	-0.549091, -0.376093, -0.607811
60	88888.9	-0.236364, -0.358601, -0.462978
61	-88888.9	-0.236364, -0.381924, -0.332791
62	-88888.9	-0.563636, -0.516035, -0.21725
63	-88888.9	-0.0527273, -0.883382, -0.62083
64	-88888.9	1, 0.48105, -0.728234
65	88888.9	1, -0.0174927, -0.728234
66	88888.9	-0.236364, -0.381924, -0.576892
67	-88888.9	-0.781818, -0.714286, -0.710334
68	-88888.9	-0.549091, -0.795918, -0.607811
69	-88888.9	-0.527273, -0.705539, -0.775427
70	-68863.3	-0.818182, -0.854227, -0.809601
71	88888.9	-0.610909, -0.921283, -0.529699
72	-88888.9	-0.781818, -0.825073, -0.793328
73	88888.9	-0.8, -0.755102, -0.554109

74	-88888.9	-0.8, -0.460641, -0.570382
75	11261.1	0.0909091, -0.638484, -0.907242
76	88888.9	-0.527273, -0.723032, -0.545972
77	-88888.9	-0.808727, -0.629738, -0.601302
78	-67882.2	1, 0.300292, -0.728234
79	88888.9	-0.745455, -0.892128, -0.674532
80	-45345.3	-0.62, -0.428571, 1
81	-42824	-0.236364, 0.0408163, -0.495525
82	-88888.9	-0.625455, -0.915452, -0.389748
83	88888.9	-0.818182, -0.708455, -0.542718
84	-88888.9	-0.345455, -0.793003, -0.915378
85	-88888.9	-0.694909, 0.638484, 0.404394
86	88888.9	-0.625455, -0.03207, -0.389748
87	-88888.9	-0.745455, -0.801749, -0.668023
88	88888.9	-0.659273, -0.912536, -0.228641
89	-88888.9	-1, -0.35277, -0.853539
90	-88888.9	-0.195273, -0.947522, -0.663141
91	-88888.9	-0.781818, -0.720117, -0.705452
92	88888.9	-0.527273, -0.548105, -0.664768
93	88888.9	-0.818182, -0.690962, -0.809601
94	84913.5	1, 0.48105, -0.728234
95	-64583.4	0.272727, -0.35277, -0.853539
96	88888.9	-0.302545, -1, 0.977217
97	-88888.9	-0.625455, -0.915452, -0.389748
98	88888.9	-0.745455, -0.723032, -0.785191
99	26851.2	-0.62, 0.317784, -0.158666
100	88888.9	-0.625455, -0.411079, -0.389748
101	-45264.7	-0.527273, -0.373178, -0.853539
102	37881.6	-0.62, -0.0408163, -0.158666
103	-88888.9	-0.709091, -0.892128, -0.783564
104	-88888.9	-0.781818, -0.822157, -0.697315
105	88888.9	-1, -0.620991, -0.853539
106	17141.9	0.0545455, -0.889213, -0.729862
107	-88888.9	-1, -0.635569, -0.609439
108	88888.9	-0.563636, -0.580175, -0.103336
109	-88888.9	-0.527273, -0.623907, -0.853539
110	88888.9	-0.781818, -0.941691, -0.62083
111	70264.4	-1, -0.35277, -0.853539
112	74879.8	-0.527273, -0.201166, -1

113	88888.9	-0.563636, -0.332362, -0.13751
114	88888.9	-0.418182, -0.830904, -0.913751
115	-88888.9	-0.418182, -0.833819, -0.910496
116	88888.9	-0.527273, -0.927114, -0.653377
117	88888.9	-0.563636, -0.883382, -0.178194
118	-88888.9	-0.62, -0.539359, 1
119	88888.9	-0.527273, -0.539359, -0.882832
120	88888.9	-0.527273, -0.74344, -0.889341
121	-41855.7	-0.445091, -0.61516, -0.0919447
122	88888.9	-0.563636, -0.883382, -0.178194
123	88888.9	-0.818182, -0.690962, -0.809601
124	81511.7	0.272727, -0.0466472, -1
125	88888.9	-0.527273, -0.620991, -0.762408
126	-88888.9	-0.745455, -0.723032, -0.830757
127	-87959.5	-0.302545, -0.997085, 0.973963
128	-63222	-0.345455, -0.787172, -0.918633
129	-88888.9	-0.659273, -0.906706, -0.493897
130	-88888.9	-0.709091, -0.877551, -0.801465
131	88888.9	-0.709091, -0.758017, -0.791701
132	88888.9	0.272727, -0.626822, -0.853539
133	88888.9	-0.527273, -0.708455, -0.542718
134	88888.9	-0.659273, -0.944606, -0.627339
135	88888.9	-0.8, -0.83965, -0.536208
136	-88888.9	-0.625455, -0.915452, -0.389748
137	-88888.9	-0.527273, -0.816327, -0.664768
138	57766.8	-0.62, -0.539359, 1
139	-88888.9	-0.625455, -0.810496, -0.389748
140	88888.9	-0.527273, -0.696793, -0.558991
141	88888.9	-0.527273, -0.755102, -0.882832
142	88888.9	-0.8, -0.641399, -0.578519
143	88888.9	-0.527273, -0.816327, -0.560618
144	88888.9	-0.563636, -0.819242, -0.13751
145	-88888.9	0.272727, -0.725948, -0.609439
146	-88888.9	-0.236364, -0.588921, -0.726607
147	88888.9	-0.527273, -0.819242, -0.555736
148	88888.9	-0.745455, -0.723032, -0.830757
149	88888.9	-0.898182, -0.883382, -0.627339
150	88888.9	-0.527273, -0.54519, -0.66965
151	-88888.9	-0.236364, -0.594752, -0.495525

152	88888.9	-0.709091, -0.900875, -0.7738
153	88888.9	-0.818182, -0.854227, -0.809601
154	88888.9	0.272727, -0.367347, -0.853539
155	-88888.9	-1, -0.720117, -0.609439
156	88888.9	-0.8, -0.501458, -0.539463
157	-88888.9	-0.709091, -0.588921, -0.788446
158	88888.9	-0.610909, -0.705539, -0.521562
159	88888.9	-1, -0.632653, -0.853539
160	88888.9	-0.898182, -0.612245, -0.656631
161	88888.9	-0.0527273, -0.915452, -0.557364
162	88888.9	-0.745455, -0.77551, -0.558991
163	-27416.4	-1, -1, -1
164	-88888.9	-0.625455, 1, -0.389748
165	-5921.62	-1, -0.0466472, -1
166	88888.9	-0.62, 0.294461, 1
167	-88888.9	-0.781818, -0.895044, -0.599675
168	88888.9	-0.236364, -0.597668, -0.889341
169	-88888.9	-0.781818, -0.83965, -0.570382
170	84743.2	-0.694909, 0.638484, 0.404394
171	88888.9	-0.709091, -0.758017, -0.791701
172	88888.9	-0.610909, -0.0932945, -0.570382
173	-88888.9	-0.625455, -0.609329, -0.389748
174	-88888.9	-0.563636, -0.0670554, -0.215622
175	-14218	0.272727, -0.728863, -0.609439
176	-88888.9	-0.709091, -0.594752, -0.783564
177	-80821.4	-0.62, 0.294461, 1
178	-88888.9	-0.549091, -0.795918, -0.607811
179	-88888.9	-0.527273, -0.591837, -0.677787
180	62825.9	-0.625455, -0.03207, -0.389748
181	-88888.9	-0.625455, -0.810496, -0.389748
182	-88888.9	-0.781818, -0.825073, -0.593165
183	88888.9	-0.890909, -0.708455, -0.567128
184	-19957.2	-0.527273, -0.994169, 0.0903173
185	-88888.9	-0.527273, -0.845481, -0.542718
186	-51260.4	-1, -0.626822, -0.609439
187	-88888.9	-0.709091, -0.77551, -0.778682
188	-88888.9	-0.625455, -0.810496, -0.389748

189	88888.9	-0.236364, -0.358601, -0.283971
190	-122.445	1, 1, 1
191	88888.9	-0.527273, -0.539359, -0.672905
192	88888.9	-0.898182, -0.6793, -0.593165
193	88888.9	-0.527273, -0.553936, -0.874695
194	-88888.9	-0.781818, -0.813411, -0.708706
195	-88888.9	-0.709091, -0.580175, -0.791701
196	88888.9	0.272727, -0.731778, -0.609439
197	88888.9	-0.185455, -0.723032, -0.965826
198	88888.9	-0.610909, -0.845481, -0.554109
199	88888.9	0.0545455, -0.854227, -0.7738
200	-88888.9	-0.563636, -0.311953, -0.163548
201	88888.9	-0.818182, -0.941691, -0.809601
202	18318.5	-0.527273, -0.48105, 0.0903173
203	-88888.9	1, 0.48105, -0.728234
204	88888.9	1, 0.48105, -0.728234
205	88888.9	-0.781818, -0.740525, -0.684296
206	88888.9	-0.898182, -0.842566, -0.640358
207	58986.2	-0.236364, -0.594752, -0.495525
208	88888.9	-0.745455, -0.772595, -0.702197
209	88888.9	-0.563636, -0.895044, -0.13751
210	-88888.9	-0.62, 0.950437, 1
211	88888.9	-0.563636, -0.294461, -0.178194
212	-88888.9	-0.62, -0.527697, -0.158666
213	-88888.9	-0.625455, -0.03207, -0.389748
214	-68085.4	1, -0.0174927, -0.728234
215	88888.9	-0.236364, -0.212828, -0.495525
216	86645.2	-0.781818, -0.717201, -0.804719
217	88888.9	1, 0.48105, -0.728234
218	-88888.9	-0.745455, -0.778426, -0.697315
219	88888.9	-0.527273, -0.798834, -0.583401
220	-88888.9	-0.563636, -0.12828, -0.163548
221	-5234.68	-0.709091, -0.769679, -0.783564
222	88888.9	-0.709091, -0.886297, -0.790073
223	-23562.1	-0.236364, -0.594752, -0.332791
224	88888.9	-0.527273, -0.921283, -0.661513
225	-88888.9	-0.195273, -0.932945, -0.539463
226	-88888.9	-0.625455, 1, -0.389748
227	88888.9	-0.781818, -0.938776, -0.624085

228	88888.9	-0.527273, -0.723032, -0.545972
229	-88888.9	-0.527273, -0.941691, -0.755899
230	88888.9	1, 0.48105, -0.728234
231	88888.9	-0.610909, -0.862974, -0.521562
232	-88888.9	-0.659273, -0.906706, -0.646867
233	-88888.9	-0.625455, -0.03207, -0.389748
234	88888.9	-0.62, -0.428571, 1
235	-88888.9	-0.8, -0.827988, -0.557364
236	88888.9	-0.818182, -0.941691, -0.809601
237	72388.5	-0.927273, -0.708455, -0.542718
238	-88888.9	-0.781818, -0.895044, -0.599675
239	-88888.9	-0.527273, -0.629738, -0.755899
240	88888.9	-0.781818, -0.708455, -0.567128
241	88888.9	-0.527273, -0.379009, -0.853539
242	-88888.9	-0.236364, -0.565598, -0.903987
243	-88888.9	-0.625455, -0.03207, -0.389748
244	88888.9	-0.62, 0.982507, -0.158666
245	88888.9	1, -0.227405, -0.728234
246	88888.9	-0.195273, -0.892128, -0.612693
247	-88888.9	-0.781818, -0.819242, -0.799837
248	-88888.9	-0.527273, -0.734694, -0.752644
249	10221.4	-1, -0.728863, -0.853539
250	-88888.9	0.0909091, -0.629738, -0.910496
251	88888.9	-0.527273, -0.825073, -0.653377
252	-88888.9	-0.527273, -0.93586, -0.76729
253	-57612.8	-0.527273, -0.842566, 0.0903173
254	88888.9	-0.625455, 1, -0.389748
255	-88888.9	-0.236364, -0.381924, -0.495525
256	88888.9	-0.610909, -0.137026, -0.545972
257	-80999.7	-0.709091, -0.594752, -0.783564
258	-70972.9	-0.195273, -0.96793, -0.668023
259	-88888.9	-0.781818, -0.71137, -0.809601
260	-88888.9	-0.334545, -0.457726, -0.908869
261	-87673.6	-0.62, 0.982507, -0.158666
262	-1584.33	-0.625455, 1, -0.389748
263	-66672.8	-0.236364, -0.381924, -0.495525
264	88888.9	-0.625455, 1, -0.389748
265	-88888.9	-0.625455, -0.915452, -0.389748
266	-88888.9	1, -0.0174927, -0.728234
267	88888.9	1, 0.48105, -0.728234
268	88888.9	-0.527273, -0.749271, -0.887714
269	88888.9	-0.898182, -0.819242, -0.617575
270	-38777	1, -0.399417, -0.728234
271	-88888.9	1, 0.48105, -0.728234
272	88888.9	-0.527273, -0.737609, -0.894223
273	88888.9	-0.527273, -0.717201, -0.532954