EVALUATION OF INTERFERENCE FACTOR AMONG TALL BUILDINGS USING GENETIC PROGRAMMING

A thesis Submitted
in partial fulfillment of the requirement for
the award of the degree of

MASTERS OF ENGINEERING
IN
STRUCTURAL ENGINEERING

Submitted By:

S K BAKSHI

Roll no. 821122015

Under the Guidance of

Dr. Naveen Kwatra

Head and Associate Professor

CIVIL ENGINEERING DEPARTMENT

THAPAR UNIVERSITY,

PATIALA-147004

JULY 2014

DECLARATION

I hereby declare that the thesis report entitled **"Evaluation of Interference Factor among Tall Buildings using Genetic Programming"** is an authentic record of the work carried out as the requirement for the award of Master of Engineering in Structure at Thapar University, Patiala under the guidance of **Dr. Naveen Kwatra, Associate Professor & Head, Department of Civil Engineering** during the period January to June, 2014.

Date: 14 Jul 2014

S K Bakshi
(821122015)

CERTIFICATE

This is to certify that above statement is correct to best of my knowledge and belief.

Dr. Naveen Kwatra
Associate Professor
Thapar University,
Patiala

Dr. S.K. Mohapatra
Dean of Academic Affairs
Thapar University
Patiala

ACKNOWLEDGEMENT

Thesis is indeed the most important and integral part of our curriculum at the Civil Engineering Department at Thapar University, Patiala.

I would like to convey my gratitude to my esteemed and worthy supervisor, **Dr. Naveen Kwatra (Associate Professor & Head)**. I am truly indebted for their advice and guidance. Their abundant knowledge in civil and construction field is a benefit for me.

The preparation of this project report would not have been possible without the support of invaluable inputs from key individuals. This report required hard work, sincerity and devotion which I tried my best to put in this project and in turn gained a lot of knowledge and confidence from this report.

I would like to extend my gratitude to all my colleagues especially Salman & Vipin who have provided assistance on various occasions. I truly value their assistance and valuable views. I would also like to acknowledge the contribution of Ms Divya Aggarwal, who has always been a source of sunshine for me and always be there to help me out despite her busy schedule. I render my gratitude to Almighty and to my lovely wife who bestowed self confidence, ability and strength in me to complete this work.

I would like to end by saying that the people mentioned above will hold dear in my heart and will never be forgotten. Thank you all.

S K Bakshi

(821122015)

ABSTRACT

Wind loading on Tall buildings has been an area of active investigations due to increasing public concern towards severe damage caused by wind storms in recent years. Design wind loading is mainly obtained from different codes, wherein the major source of information on which specifications are based is wind tunnel testing of scaled rigid models under simulated flow. Any tall building can vibrate in both the directions of Along wind and Across wind caused by the flow of wind. Modern tall buildings designed to satisfy lateral drift requirements, still may oscillate excessively during wind storm. These oscillations can cause some threats to tall buildings as buildings with more and more height becomes more vulnerable to oscillate at high winds. Sometimes these oscillations may even cause discomfort to the occupants even if it is not in a threatening position for the structural damage. One successful tall building in a particular location attracts more such constructions there. The final scene of a society center thus consists of one or more tall building(s) surrounded by a few medium rises and many low rise structures and other topographical features. The wind pattern is bound to change due to presence of other buildings in vicinity causing either shielding or increased wind pressure coefficients on test building.

The study reported in this thesis is an effort to examine the efficacy of Genetic Programming (GP) to predict the aerodynamic Interference in tall rectangular buildings on the basis of the data obtained from the wind tunnel testing done by Gupta (1996). Data collected on wind induced interference effects on building has been analyzed and compared in order to identify common points of agreement and area of concern. Given the limited and inconsistent available data coupled with large numbers of variables involved, empirical generalizations was difficult to obtain. In order to overcome these limitations the thesis suggests Genetic Programming (GP) approach for the assessment of wind induced interference effects on design loads for buildings. The ability of GP to be trained to generalize when presented with limited data examples makes it an attractive application for knowledge acquisition on wind interference effects where there is no acceptable theory, empirical generalization or mathematical model existing at present. The dimensions of the interfering building, reduced velocity and coordinates have been used as Input parameters for development of equations for the estimation of Interference Factor (IF) in respect of Maximum &

Mean Displacement and Acceleration in alongwind and acrosswind direction for tall buildings. The results obtained in this thesis using GP fairly describe the behavior of tall building due to Interference, although in few cases it’s at the variance to the experimental data. Still this work will provide designers a preliminary data to prepare the wind tunnel experiment setup and final results can be verified after Wind Tunnel Experiment.

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CHAPTER-1

INTRODUCTION

1.1 GENERAL

In recent years, wind loading on buildings has been an area of active investigation due to increasing public concern towards severe damage caused by windstorms. A structure that, because of its height, is affected by lateral forces due to wind or earthquake to the extent that the forces constitute an important element in structural design is known as high-rise or tall building. Tall buildings are flexible structures which tend to oscillate due to dynamic effects of wind. The wind on earth's surface is turbulent in nature that gives rise to randomly varying wind pressures about a certain value associated with the mean wind speed. The dynamic part of the wind pressures would set up oscillations in a flexible structure, which may be defined as one having the fundamental time period of vibration more than 1.0 second. Oscillations will thus be caused in the along wind direction. The IS: 875 (Part 3) - 1987 Code which gives procedure to determine along wind response of a flexible structure given by A.G. Davenport, is only applicable to a regular shape building but for an irregular shaped building behavior under the high wind speeds is provided from a prototype measurements in a wind tunnel. A simulated wind tunnel experiment on an appropriate model of the building yields results which give a deeper insight into the phenomenon and provides more precise information, overcomes the shortcomings of the analytical formulation. In the wind tunnel testing there are two approaches used for determining the response of any Tall building with an irregular or regular shape under the high wind speeds, one is the Dynamic Analysis method used to determine the wind loads on the buildings in which Base Forces can be economically obtained from HFFB test while the other one is Pressure measurement studies which are used for the safe designs of Individual structural elements as roofs and walls, and Individual cladding units including glazing and their fixing.

In recent years, the problems of wind loading and structural response have been subjected to detailed analysis and discussion. The acceleration caused in tall buildings due to wind, poses important design criteria. Many of the tall buildings have been found to become unserviceable due to acceleration during wind storms. The motion of tall buildings has been observed to occur primarily in three different modes.

For rectangular buildings, for example, with one face near perpendicular to the mean flow, the motion has been measured in the stream wise (alongwind) and transverse (acrosswind) directions, as well as in the torsional mode. Analytical formulations developed between 1960 and 1980, for along wind response have sufficiently incorporated the various parameters such that they have found a place in a number of wind loading codes. On the other hand, the acrosswind forcing mechanisms have proved to be so complex that a closed form solution, giving due weightage to different acrosswind mechanisms, is difficult to be formulated and only the semi-analytical approaches, using force spectra (based on experimental measurements), provide limited guidelines.

Buffeting and interaction from upstream buildings in an urban situation can produce strong changes in the dynamic response of a tall building. Interference effect, though first pointed out by Harris(1934) and Bailey & Vincent(1943), gained importance only after the collapse of three, out of eight, cooling towers at the Ferry Bridge Power Plant on 1st Nov.,1965[Sachs(1978)]. The cause was determined to be increased loading on the towers due to the presence of adjacent towers. Since then there is a growing awareness that the wind forces, to which tall buildings are exposed may be of a more complex nature in urban environments, than usually expected. The characteristics of oncoming flow and wake flow on one hand, together with shape, dimensions and dynamic properties of upstream as well as downstream building on the other, can be viewed as the basic interactions parameters. Till today no analytical approach or even mathematical model based on experimental results is available to predict quantitatively, the extent of interference, except for some work towards the applications of Neural Network, which is in a stage of infancy. It is evident that the owner of a new building may be held responsible for any adverse wind effect on an existing building, adding a new dimensions in litigations and professional liability [Yahyai(1990),Kwok(1995)].

The effect of interference from adjacent buildings, existing or proposed, is now routinely studied during wind tunnel model testing of tall buildings and structures. When an upstream building blocks another building, it increases or decreases the forces on the downstream building by modifying the structure of wind in its wake. Mean along wind forces on a downstream building are reduced due to shielding. This shielding clearly decreases with increase in the separation distance.

Also it would be expected that increasing the nearby structures of significant size would result in less severe wind streams, thus leading to net shielding effect, as in case of a city centre.

Keeping all this in view, in the present work an attempt has been made to study the use of Genetic programming to get equations for the Interference Factor (IF) in respect of Mean & Maximum Displacement and Acceleration in alongwind and acrosswind direction. The ability of Genetic programming to develop relationships between the input and output parameters makes it an attractive proposition for knowledge acquisition for problems where there is no acceptable theory, empirical generalisation and Mathematical Model existing at present.

Data used for obtaining equations on tall building using genetic programming is obtained from wind tunnel tests carried out by Gupta (1996) on building models. The mean response of the wind on tall buildings is influenced by various important parameters which include the geometry of the buildings, velocity of the wind and arrangement of buildings. Therefore, these parameters have been used as the Input parameters for obtaining the equations for the Interference Factor (IF) in respect of Mean & Maximum Displacement and Acceleration in alongwind and acrosswind direction.

1.2 NEED OF THE STUDY

Wind tunnel testing is generally very expensive and time consuming. In addition, the object ie the buildings to be tested is very big to fit in the tunnel itself, a very accurate scale model is to be produced and Reynolds number (a number describing the flow condition over the object) must be accurately matched to the expected operating conditions. These models can be prohibitively expensive as well. Therefore the use of Genetic Programming is manifested. The advantages of the same are listed below:

- It can solve every optimisation problem.
- It solves problems with multiple solutions.

- Since the genetic algorithm execution technique is not dependent on the error surface, we can solve multi-dimensional, non-differential, non-continuous, and even non-parametrical problems.
- Structural genetic algorithm gives us the possibility to solve the solution structure and solution parameter problems at the same time by means of genetic algorithm.
- Genetic algorithm is a method which is very easy to understand and it practically does not demand the knowledge of mathematics.
- Genetic algorithms are easily transferred to existing simulations and models.
- When the problem does not have an analytical solution.

1.3 OBJECTIVES

Application of Genetic Programming to derive an Empirical Relation for the Interference effects on a rectangular tall building from a single interfering building of different widths at upstream or downstream positions.

1.4 SCOPE OF THE WORK

In this study, Genetic Programming has been used for obtaining the equations for the Maximum and Mean displacement and acceleration alongwind and acrosswind directions for tall buildings. The mean response of the wind on tall buildings is influenced by various important parameters which include the geometry of the buildings, velocity of the wind and arrangement of buildings. Therefore, these parameters have been used as the Input parameters for obtaining the Maximum and Mean displacement and acceleration alongwind and acrosswind directions. The program has been run for various combinations of crossover rate, population size, number of generations which are randomly selected until the best fitted result is obtained. These results have been then compared with the experimental results taken from the studies carried out by Gupta (1996).

1.5 ORGANISATION OF THESIS

The thesis has been divided into Five chapters. Chapter-2 presents the review of the work carried out in various fields using Genetic Programming approach along with the works carried out on Interference in general. Chapter-3 presents the explanation of Genetic programming and the algorithm used in genetic programming. Chapter-4 presents the detailed discussion of the experimental data used and the results obtained using genetic programming on tall buildings. The results are further compared with the experimental results to analyse the difference. Conclusions of the study are summarised in chapter-5. A list of references, directly referred in the work is alphabetically arranged after chapter-5.

CHAPTER - 2

REVIEW OF LITERATURE

2.1 GENERAL

This chapter presents a review of the relevant literature to bring out the background for the study undertaken in this thesis. The literature review will be discussed in two parts. Firstly, literature relevant to Genetic Programming (GP) and its use in the other fields of civil engineering since only one study has been carried out so far in the application of GP in Wind Engineering. Secondly, the literature on Interference phenomenon among tall buildings to develop the understanding of the subject in hand.

2.2 HISTORICAL BACKGROUND TO GP

Johari et al. (2006) employed Genetic Programming approach to predict the soil-water characteristic curve (SWCC) of soils. The input set consisted of initial void ratio, initial gravimetric water content, logarithm of suction normalised with respect to atmospheric air pressure, clay content and silt content. The output set consisted of the gravimetric water content corresponding to the assigned input suction. Results from pressure plate tests carried on clay, silty clay, sandy loam and loam compiled in the Soil Vision software, were adopted as a database for developing and validating the GP model. GP software (GPLAB) provided by MATLAB was employed for analysis. GP simulations were compared with the experimental results as well as the models proposed by other investigators. The comparison indicated superior performance of the proposed model for predicting SWCC.

Heshmati et al. (2008) proposed new formulations for soil classification using Linear Genetic Programming (LGP). Properties of soil, namely liquid limit, plastic limit, colour of soil, percentage of gravel, sand and fine grained particles are used as input variables. The database used for the study was obtained from the previous published literature. The results of the proposed formulations were compared with the existing models found in the literature. From the comparisons it was observed that the LGP based formulations predicted the targeted values with higher degree of accuracy.

Kermani et al. (2009) presented the use of genetic programming for predicting the equations for the ratio of maximum velocity to maximum acceleration (v_{max}/a_{max}) of strong ground motions. The predictive equations were established using a reliable database released by Pacific Earthquake Engineering Research Center (PEER) for three types of faulting mechanisms including strike slip, normal and reverse. The proposed models provided reasonable accuracy to estimate the frequency content of site ground motions in practical projects.

Nitsure et al. (2009) used Genetic Programming to estimate an important oceanic parameter i.e. Significant Wave Height (SWH) using the wind information. Wave and wind measurements taken by moored ocean buoys were used to develop the GP models. The GP based estimations were found to have a reasonable accuracy in estimation of significant wave heights as evident from wave plots and accompanying high values of correlation coefficient.

Gandomi et al. (2010) proposed the formulation of compressive strength of carbon fibre reinforced plastic (CFRP) confined cylinders using Linear Genetic Programming (LGP). The LGP-based models were constructed using two different sets of input data. The first set of inputs comprised of diameter of concrete cylinder, unconfined concrete strength, tensile strength of CFRP laminate and total thickness of utilized CFRP layers. The second set included unconfined concrete strength and ultimate confinement pressure which were the most widely used parameters in the CFRP confinement existing models. The models were developed based on experimental results collected from the available literature. The results demonstrated that the LGP-based formulas predicted the ultimate compressive strength of concrete cylinders with an acceptable level of accuracy. The LGP results were also compared with several CFRP confinement models presented in the literature and found to be more accurate in nearly all of the cases.

Saridemir (2010) developed two models in gene expression programming (GEP) approach for predicting compressive strength of concretes containing rice husk ash at the age of 1, 3, 7, 14, 28, 56 and 90days. For purpose of building the models, experimental results for 188 specimens produced with 41 different mixture proportions were obtained from the literature. According to these experimental results, the models were arranged by using seven different input variables in GEP approach. In according to these input variables, the compressive strength values from mechanical properties of concretes containing rice husk ash were predicted in GEP approach models. The results of training, testing and validation sets of the models were compared with experimental results. All of the results showed that GEP is a strong technique for the prediction of compressive strength values of concretes containing rice husk ash.

Muduli et al. (2013) examined the potential of multi-gene genetic programming (MGGP) based classification approach to evaluate liquefaction potential of soil in terms liquefaction index (LI) using a large database from post liquefaction cone penetration test (CPT) measurements and field manifestations. The database consisted of CPT measurements; cone tip resistance (q_c), friction ratio (R_f), vertical total stress (σ_v) and vertical effective stress of soil (σ_v'), seismic parameters; peak horizontal ground surface acceleration (a_{max}) and earthquake moment magnitude (M_w), and the depth under consideration (z). The MGGP models were developed for predicting occurrence and non-occurrence of liquefaction on basis of combination of above input parameters. The performance of the models was found to be more efficient compared to available artificial neural network models.

Aggrawal & Kwatra (2013) examined wind response on tall buildings using GP. Wind response is generally estimated either through wind tunnel testing or using analytical approach as mentioned in IS875-1987, Part-3. However, both these methods are very cumbersome and time consuming. Therefore, in this paper an attempt has been made to estimate the wind response on tall buildings using Genetic Programming in the along wind direction for Long After Body and Short After Body. The database has been developed using the analytical approach as given in IS875-1987, Part-3. The building height, plan dimensions, design wind speed, gust factor and base moment have been used as the parameters for the development of the equations. The Gust Factor and Base Moment thus obtained from Genetic Programming have been thus compared with the analytical values.

2.3 BACKGROUND TO INTERFERENCE EFFECT

Between 1931 and 1936, when the Empire State Building was constructed, J.Rathbun made full-scale measurements on it **[Rathbun (1940)].** Earlier in 1933, Dryden & Hill made measurements on a five -foot scaled model of the Empire State Building. The wind sensitivity of buildings and structures depends on several factors, the most important of which are the meteorological properties of the wind, type of exposure, and the aerodynamic and mechanical characteristics of the structure, An inventory of those various factors is presented, including indications of their relative influence on the global response **[Davenport (1998)].**

Isyumov overviews the action of wind on tall buildings and structures with emphasis on the overall wind-induced structural loads and responses. Also discussed the local wind pressures on components of the exterior envelope and the effects of buildings on winds in pedestrian areas. These may include buildings and structures of unusual shape, those located in complex settings or those with dynamic systems which amplify the time varying wind forces and whose motions may in turn alter the force field. On the other hand, there is a growing population of buildings and structures for which the action of wind is well understood and can be predicted, with aerodynamic data drawn from past experience and from building codes. While we may not have all the answers, the wind engineering community has reached a stage of development which permits candidates for special attention to be identified **[Isyumov (1999)].**

Lina et al. (1999) studied nine models with different rectangular cross - sections and were tested in a wind tunnel to study the characteristics of wind forces on tall buildings. In the present paper, local wind forces on tall buildings are investigated in terms of mean and RMS force coefficients, power spectral density, and span wise correlation and coherence. The effects of three parameters, elevation, aspect ratio, and side ratio, on bluff -body flow and thereby on the local wind forces are discussed. The overall loads and base moments are obtained by integration of local wind forces. Comparisons are made with results obtained from high –frequency force balances in two wind tunnels.

Holmes & Lewis (1986, 1987 and 1989) performed extensive experimental work on the fluctuating pressure measurements using a small diameter connecting tube to transmit the pressure from the connecting point, or tap, to the pressure transducer. Their authentic work has provided sufficient guidelines to develop a range near optimum systems for the measurement of fluctuating pressure on models of the buildings in wind tunnels. In the present study the choice of tubing system for pressure measurements is largely based on the work of Holmes and Lewis (1987).

Xie et al. (2004) the mean interference effects between two and among three tall buildings are studied by a series of wind tunnel tests. Both the shielding and channelling effects are discussed to understand the complexity of the multiple-building effects. The results show that the upstream interfering buildings cause certain shielding effect by decreasing the mean wind load on the downstream principal building. For buildings of the same height, the shielding effect increases and, therefore, the interference factor (IF) decreases, with the increase of the breadth of the interfering buildings. However, due to the channelling effects, two adjacent interfering buildings can significantly enhance the mean wind load on the principal building. In addition, the variation of the shielding effect is found to be significant when the heights of interfering buildings range from 50% to 125% of the height of the principal building. However, higher interfering buildings may cause stronger channelling effects.

Lam et al. (2006) applied CFD to visualize wind flow around a row of three square-plan tall buildings closely arranged in a row. Increase in wind load on the upwind building is observed when wind blows to the row at 30 degree. CFD results show that the interference mechanism is mainly due by strong channelling of wind flow through the building gaps. This leads to highly negative pressures on building walls facing a gap.

Xie et al. (2006) studied the base-bending moment (BBM) response and the mean BBM of grouped high-rise buildings by a series of wind tunnel tests on typical tall building models using the high-frequency force balance technique. Interference excitations of two upwind buildings with various heights in different upwind terrains are considered. An effective method is proposed to represent the distribution of the envelope interference factor (EIF) among three tall buildings. The results show that two upstream buildings cause more adverse dynamic effects on the downstream building than a single upstream building does. Significant correlations are found in the distributions of the interference factors of different configurations and upwind terrains. Relevant regression equations are proposed to simplify the complexity of the multi-parameter wind-induced mean and dynamic interference effects among three tall buildings. Finally, an example of how to use the data provided in this paper and the proposed methodology is presented.

Kim et al. (2009) investigates local peak wind pressure coefficients on two tall buildings using wind tunnel experiments for various locations of an interfering building and several wind directions for cladding design. Measured wind pressure coefficients were compared with those on the walls of an isolated building. Also, to investigate the interference effects for smallest *Cp*,min for several wind angles, interference effects are presented in detail. The results show that the local peak wind pressure coefficient on the walls of a principal building largely depended upon the location of an interfering building in the walk region and upon the wind angles.

Lam et al. (2011) studies wind-induced interference effects on a row of five square-plan tall buildings arranged in close proximity. Mean and fluctuating wind loads are measured on each building member and wind-induced dynamic responses of the building are estimated with the high-frequency force- balance technique. The modifications of building responses from interference over a practical range of reduced velocities are represented by an envelope interference factor. Wind tunnel experiments and response analysis are carried out under all possible angles of wind incidence, at four different building separation distances, and for two arrangement patterns of buildings in the row, that is the parallel and diamond patterns. It is found that building interference leads to amplified dynamic responses in many cases but reduction in responses also occurs at some wind incidence. For a building row of the parallel pattern, five distinct wind incidence sectors of different levels and mechanisms of interference effect can be identified. The largest values of envelope interference factors can reach 2.4 for the torsional responses. When the row of tall buildings is arranged in the diamond pattern, increase in wind excitation occurs at many wind angles due to a ‘‘wind catchment’’ effect. The interference factors have larger peak values, reaching 2.1 in the sway directions and above 4 in torsion. However, all large amplifications of building responses do not occur in the situations of peak resonant dynamic responses of the single isolated building. Thus, the design values of peak dynamic responses of a tall building are not significantly magnified when placed in a row.

Yi et al. (2012) studies the interference effects of wind loads on a real project with three similar- shaped staggered arranged tall buildings, wind tunnel tests about the three tall buildings and one isolated tower were conducted respectively. By comparison of the measured results, effects of wind directions and building positions on the design wind forces for main wind-force resisting system, i.e., along-wind, cross-wind and torsion wind loads, were discussed. Interference mechanisms were analyzed by integrating CFD simulated results and experiment measured data. It indicates that wind loads of the middle tower, are greatly increased compared to isolated cases and in the unfavourable wind direction of 110 degree, the static interference factor of torsion load, dynamic interference factor of wind load in Y and torsion directions are 1.53, 1.32 and 1.37 respectively.

Hui et al. (2012) investigates the interference effects between two high-rise buildings with different shapes by wind tunnel experiments, focusing on local peak pressure coefficients. To examine the interference effects for local peak pressures in detail ,interference factors for maximum positive and minimum negative peak pressures at each measurement point ''i'' of the principal building for all wind directions are presented and discussed. The results show that these effects greatly depend on building shape and wind directions. They also show that special care should be taken with cladding design at the vertical edges, especially corners of buildings, since the smallest minimum peak pressure on a building face might be 40% larger than in the isolated condition.

Han et al. (2012) studied the interference effect on wind pressure between two identical buildings was by wind tunnel tests for different locations of the interfering building .The results show that for the tandem configurations, mean pressure on windward face of the principal building is suction when spacing ratio is less than 3.0, otherwise it is positive. The magnitude of mean negative pressure on the side and leeward faces and fluctuating pressure on all faces get maximums when spacing ratio is 3.0.With an increase in spacing ratio for the side-by-side arrangements, the maximum value of mean and fluctuating pressure coefficient interference factor decreases on the inner and outer face while slightly increases on the front and rear face. Notably, the fluctuating pressure coefficient interference factor on the inner face grows visibly and the maximum value is 2.2 on the top leading corner when the spacing ratio is 2.0.

Hui et al. (2013) investigates the interference effects between two rectangular-section high- rise buildings by wind tunnel experiments, focusing on local peak pressure coefficients. Wind tunnel experiments were carried out under 72 wind incidence angles for various configurations. Two building arrangements were considered: parallel and perpendicular. To evaluate the interference effects for local peak pressures in detail, interference factors for largest positive and smallest negative peak pressures are presented and discussed. The results show that interference effects greatly depend on configuration and wind direction. Unfavourable positions are generally concentrated at the edges and corners of a building. Flow visualization was also conducted to check the flow field between two buildings.

2.4 CLOSURE

One issue that dominates the serviceability design of many modern tall buildings is wind- induced discomfort. The assessment of discomfort risk for building occupants due to wind action is therefore, of primary importance. It can be properly carried out only through a reliable estimation of the acceleration responses which, particularly in the across wind direction, may be influenced by aeroelastic effects. In the absence of any reliable Analytical approach, experimental data is the only medium to ascertain the case specific requirements of a building under construction. Comparison with previous studies also shows that a more systematic study on interference effects is needed so as to develop an authentic database. The database so developed can be processed through GP application to ascertain the results due to Interference and in a time to come, the costly and time consuming wind tunnel experiment can be emitted.

CHAPTER – 3

GENETIC PROGRAMMING

3.1 GENERAL

Genetic Programming (GP) is a domain independent, problem-solving approach in which computer programs (which in general are the equations) are evolved to find solutions to the problems. The solution technique is based on the Darwinian principle of 'survival of the fittest'. Genetic Programming (GP) is similar to genetic algorithm (GA) but unlike the latter its solution is a computer program or an equation as against a set of numbers in the GA. (Gaur and Deo, 2008).

Genetic programming is a search technique that explores the space of computer programs. The search for solutions to a problem starts from a group of points (random programs) in the search space. Those points that are of above average quality are then used to generate a new generation of points through crossover, mutation, reproduction and possibly other genetic operations. This process is repeated over and over again until a termination criterion is satisfied. Because genetic programming is a stochastic search technique, in different runs different trajectories are observed.

Therefore, many real runs are performed and variations of certain numerical descriptors (like the average fitness or the average size of the programs in the population at each generation, the average difference between parent and offspring fitness, etc) are recorded. The result which is finally compatible with the empirical observation is considered.

This exercise is very error prone, though, because a genetic programming system is a complex adaptive system with zillions of degrees of freedom. So, any small number of statistical descriptors is likely to be able to capture only a tiny fraction of the complexities of such a system.

3.2 PRIMITIVES OF GENETIC PROGRAMMING

Every solution evolved by GP is assembled from two sets of primitive nodes; terminals and functions. The terminal set contains nodes that provide an input to the GP system. The terminal set contains the arguments for the function and consists of variables or numerical constants. The function set contains nodes that process values already in the system which may be arithmetical operations such as +, -, mathematical operations such as log, exponential, sin, cos etc. Constants may also be used in GP by including them in the terminal set. The primitives of GP, the function and terminal nodes, are then assembled into a structure before they are executed.

3.3 ALGORITHM OF GENETIC PROGRAMMING

The genetic programming paradigm breeds computer programs to solve problems by executing the following three steps:

1. An initial population of individual computer programs is randomly created composing the available functions and terminals.

2. The initial population is now tested for its fitness. The best fitted individual program is then selected for participating in the genetic operations to be conducted to form a new population. Fitness may be measured in many different ways such as coefficient of determination (COD), root mean square error (RMS), Unit Error (deviation from dimensional error) and fitness per node (measurement of the simplicity of the expression of the individuals). The population can be tested by some or all the fitness parameters mentioned above.

3. Various genetic operators are now applied to the best fitted individual program to form a new individual program(s) for the new population. There are three major evolutionary operators within a GP system:

Reproduction: selects an individual from within the current population to be copied exactly into the next generation. In fig.3.1 individual (a) of the current population is as such copied into the new population as the individual (a) in fig.3.2.

Crossover: mimics sexual recombination in nature, where two parent solutions are chosen and parts of their sub tree are swapped. In fig. 3.1 individuals (a) and (b) are the two parents chosen for the crossover operation. The + function of parent (a) and leftmost terminal x of parent (b) are swapped to form individuals (c) and (d) of the new population in fig.3.2.

Mutation: causes random changes in an individual before it is introduced into the subsequent population. Unlike crossover, mutation is asexual and thus only operates on one individual. During mutation, either all functions and terminals are removed beneath an arbitrarily determined node and a new branch is randomly created, or a single node is swapped for another. In fig 3.1 individual (c) is muted wherein terminal

2 is picked as the mutation site and a sub tree is inserted in its place which again is randomly created to form a individual (b) of the new population in fig.3.2.

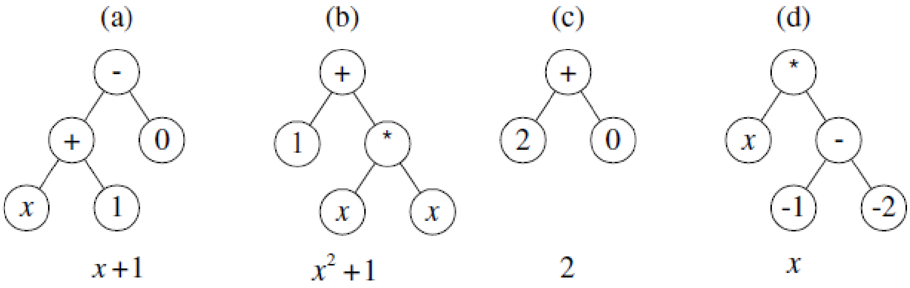


Fig.3.1 Initial population of four randomly created individuals

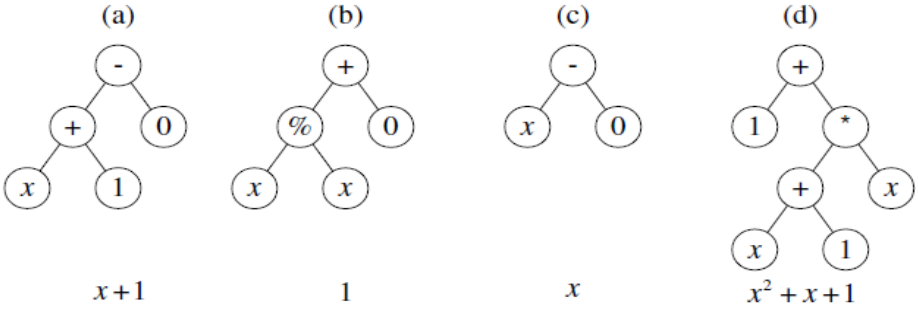


Fig.3.2 New Population (a) After Reproduction, (b) After Mutation and (c),(d) After Crossover Operation

After the above mentioned operations are performed on the current population, the population of offspring (i.e., the new generation) replaces the old population (i.e., the old generation).Each individual in the new population of computer programs is then again measured for fitness, and the process is repeated for many generations. However, the genetic programming is a never ending process and therefore it is required to define some control parameters. Some of the control parameters that are required to be set are as follows:-

1. Population size: A larger population allows a greater exploration of the problem at each generation and increases the chance of evolving a solution.

2. Maximum number of generations: The greater the maximum number of generations the greater the chance of evolving a solution. However, even if after the evolution of a population, a solution is not found then it is better to start again with a different initial population. However if, after a user-defined number of generations, a sufficiently successful individual has not evolved then the process should stop.

3. Probability of crossover is the proportion of the population that will undergo crossover before entering the new population. If the probability of crossover is 0.90 it means that the crossover is performed on 90% of the population for each generation.

4. Probability of reproduction is the proportion of individuals in a population that will undergo reproduction.

Flowchart for the genetic programming paradigm has been presented in figure 3.3. (Koza, 1992)

3.4 ADVANTAGES OF GENETIC PROGRAMMING

A key advantage of GP when compared to traditional modelling approaches is that it does not assume a prior functional form of the solution. For instance, in a typical regression method, the model structure is specified in advance (which is in general difficult to do) and the model coefficients are determined. For neural networks, the time consuming task of initially defining the network structure has to be undertaken and then the coefficients (weights) are found by the learning algorithm. On the other hand, in GP, the building blocks (the input and target variables and the function set) are defined initially, and the learning method subsequently finds both the optimal structure of the model and its coefficients. Moreover, since GP evolves an equation or formula relating to the input and output variables, a major advantage of the GP approach is its automatic ability to select input variables that contribute beneficially to the model and disregard those that do not. GP can thus reduce substantially the dimensionality of the input variables. However, a common limitation of GP is that it cannot handle more numbers of constants. In GP, as in any data-driven prediction model, the selection of appropriate model input is extremely important. Inclusion of irrelevant input parameters leads to poor model accuracy and creation of complex models, which are more difficult to interpret as compared to simpler ones.

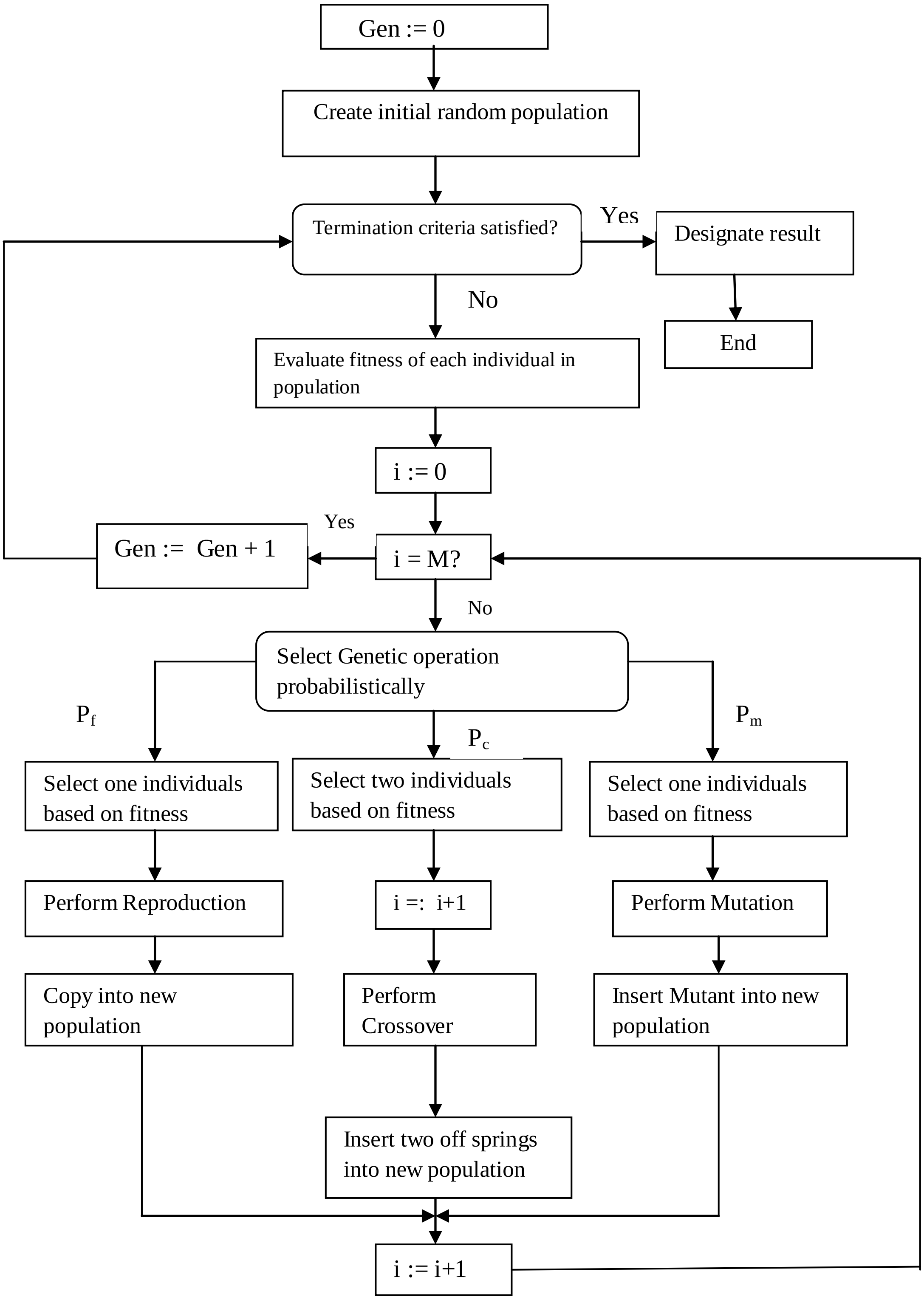


Fig. 3.3 Flowchart of Genetic Programming

CHAPTER – 4

STUDY OF INTERFERENCE EFFECT

4.1 General

Wind forces on buildings are usually dealt with considering the building in isolation. Contrary to this, a large number of buildings are situated in an urban environment and hence surrounded by other buildings and structures. Thus flow fields of buildings interfere with each other, thus creating a wind field which is different in comparison to that for the isolated building. Aerodynamics interference between two buildings has been found to change the response of each of them significantly due to flow modifications. The buildings on the downstream side gets affected much more. Prediction of wind loads and the response of the building become difficult in such cases. Additional complexity arises due to the presence of one building in the wake of another or wakes of a number of other buildings undergoing complicated wake interaction. The effect of interference in a given situation depends very much on the position of the building group relative to wind direction, leading either to shelter or to amplification effect. A detailed account of the developments in the field of understanding the interference effects is chapter 2. Generalisation of interference magnitude and pattern has not been possible from previous studies since these have been carried out on different sets of building and often in different flow conditions. Though for a similar shape and sized building, compilation of available data may yield some guidelines. In the present study an attempt has been made using Genetic Programming to minimise the effort involved in the analytical analysis as well as the wind tunnel testing for evaluation of Interference Factors (IF). The experimental data evolved by Gupta (1996) has been made basis for the study since no analytical data is available so far.

4.2 Experimental Data used in the Study

4.2.1 The Prototype

The prototype selected for the study by Gupta (1996) is a hypothetical tall building with rectangular cross-section. The height, width and depth of the building are 240m, 24m, and 48m respectively. The building is assumed to have a steel frame construction with masonry panels and light weight cladding for façade. Other salient characteristics are as follows:

Building bulk density = 190 kg/^{m3}
Time periods of vibrations = 5.20 sec, for long after body
=6.25 sec, for short after body
Critical damping ratio = 0.015, for both the directions
Fundamental mode shape = Linear
Aspect ratio (D/b) = 2.0
Slenderness ratio ($h/\sqrt{A}$) = 7.07

The prototype is considered to be situated in a suburban terrain, defined as terrain category 3 in IS-875 (pt.3)-1987. The variation of hourly mean wind speed is assumed to follow a power law with coefficient α=0.18. The building is considered located in Zone-III (Green Zone) in Fig.1 of IS-875. Here the basic wind speed at 10m reference height is 47 m/s, based on 3 sec gust and 50 years return period. Design wind speeds are obtained by multiplying this speed by suitable factors given in Table 33 of IS-875 for hourly mean velocity. In the study a 1:400 scaled wind model is used over a 1m thick boundary layer.

The interfering model, which are rigid, have been placed at different positions, upstream and downstream as well as side-by-side, and the alongwind and acrosswind responses, viz, displacements and accelerations of the aeroelastic building model have been studied. The interfering models have been designated as R1, and R2 with plan to height proportions as follows:

R1 - 1:1:10 (Square plan b x d x h)
R2 - 2:1:10 (Rectangular 1:2 in plan b x d x h)

The plan dimensions have been chosen to represent small and large width to length ratio. The response of the aeroelastic model is varied between 2b and 20b longitudinally upstream, 2b to 4b longitudinally downstream and upto 4b in the transverse direction at grid spacing of b. This corresponds to an area of 480m*192m on the upstream and 96m*192m on the downstream side at full scale. The various response parameters for a particular wind speed have been normalised by the corresponding ones for the isolated case and have been termed as “Buffeting Factor” for the particular wind speed.

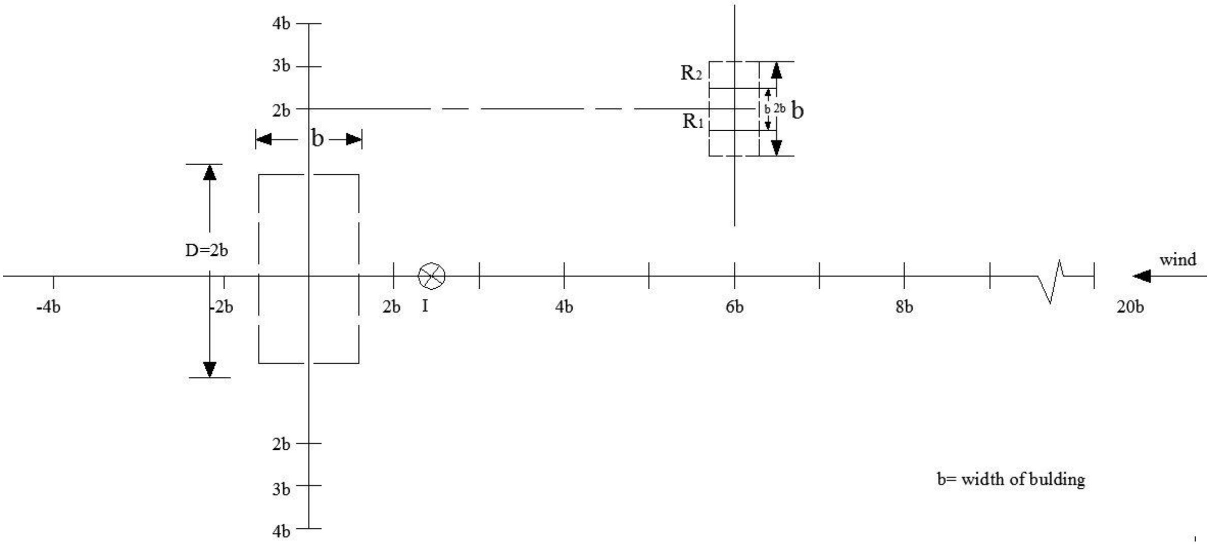


Fig.4.1 Experimental Setup

4.2.2 Results obtained from Experimental study

The study is performed at three different wind speeds. The reduced velocity calculations are based on broader face width of the aeroelastic model and the natural frequency of vibration in the respective direction. The interfering models are oriented with their broader face normal to the wind. The test building is aligned with its broad face perpendicular to the direction of wind. The contours of IFs, for all response parameters, at two different wind speeds are presented. The contours are shown only once during comparison with contours derived using GP to avoid duplication.

(a) Mean Alongwind Displacement (Mean ALDSP)

Mean alongwind response is not significantly altered by any of the interfering models. The max IFs lies between 0.96 and 1.15. Max IF on the upstream side occurs with R2 at (10b,4b) position . Max IF on the downstream side is larger than on the upstream side, equal to 1.15 with R2 at (-3b,4b) and occurs at reduced velocities of 6.03 to 8.82.

(b) Max Alongwind Displacement (Max ALDSP)

The critical interfering locations for the total alongwind response lie between 7b and 10b upstream with 2b-4b offsets and at (-3b, 4b) downstream, since the max IF lie in this range and yield the maximum ALDSP. Observations show that max IF lie between 1.28 and 1.55. On the downstream side slightly lower IFs are observed. The maximum IF as well as max response both occur with R2 at (8b,4b) for a reduced velocity of 8.82. On the downstream side both max IF and maximum model response occur at (-3b,4b) position.

(c) Peak Acrosswind Displacement (Peak ACDSP)

The critical interfering locations for the total acrosswind response lie between 4b and 10b upstream and at (-3b, 4b) downstream, since the max IF lie in this range and yield the peak ALDSP. Observations show that max IF lie between 2.5 and 10.0. On the downstream side slightly lower IFs are observed. On the downstream side both max IF and maximum model response occur at (-3b,4b) position.

(d) Peak Acrosswind Acceleration (Peak ACACN)

The critical interfering locations for the total acrosswind response lie between 1b and 10b upstream and at (-3b, 4b) downstream, since the max IF lie in this range and yield the peak ACACN. Observations show that max IF lie between 5.2 and 10.5. On the downstream side slightly lower IFs are observed. On the downstream side both max IF and maximum model response occur at (-3b,4b) position.

4.3 Application of Genetic Programming for predicting IF in respect of para 4.2.2 (a) to (d)

The mean response of the wind on tall buildings is influenced by various important parameters which include the geometry of the buildings, velocity of the wind and arrangement of buildings. Therefore, these parameters have been used as the Input parameters for obtaining the equations for the Interference Factor (IF) in respect of Mean & Maximum Displacement and Acceleration in alongwind and acrosswind direction. The equations for IFs have been developed using the values of input and output parameters for various combinations of crossover rate, number of generations, population size and number of children to produce. This process is continued until the most accurate equations are obtained by reaching the maximum number of generations. The statistic measures used to assess the accuracy of these equations are Coefficient of Determination (COD) and Root Mean Square (RMS) wherein the objective is to have COD nearly equal to 1 and RMS nearly equal to 0. The actual values of COD and RMS that have been achieved in the development of the equations vary from 0.79 to 0.85 for COD and 0.11 to 0.26 for RMS. Sample input and output parameters have been tabulated below and details of Input / Output data used along with comparison of results are attached as Appendix. All input and output data can be extracted from contours shown in subsequent pages of this chapter.

Table-4.1 Table showing the Sample Database used by GP

B	D	H	RV	X	Y	EXPERIMENTAL IF	IF DERIVED USING GP
24	24	240	6.03	240	0	0.6	0.59023
24	24	240	6.03	240	24	0.7	0.66767
24	24	240	6.03	240	48	0.8	0.75414
24	24	240	6.03	240	72	0.9	0.84511
24	24	240	6.03	240	96	1	0.93867
24	24	240	6.03	216	0	0.55	0.61058
24	24	240	6.03	216	24	0.675	0.68223
24	24	240	6.03	216	48	0.8	0.765451

The results obtained using Genetic programming is fairly matching with the results obtained from experiments. The details are as follows:-

(a) Mean Alongwind Displacement (Mean ALDSP)

Mean alongwind response has not significantly altered by any of the interfering models. The max IFs lies between 1.05 and 1.15 which is nearly same as 0.96 and 1.15, obtained experimentally. For maximum upstream positions of interfering building, shielding is observed. No interference is observed generally near (10b,4b) point. Max IF on the downstream side is larger than on the upstream side.

(b) Max Alongwind Displacement (Max ALDSP)

Max alongwind response is altered significantly with a max IFs lies between 1.1 to 1.59, which is quite similar to experimental results being 1.28 to 1.55.The critical interfering locations for the total alongwind response lie between 6b and 10b upstream and at (-3b, 4b) downstream with R2 building at reduced velocity of 6.03. On the downstream side slightly lower IFs are observed.

(c) Peak Acrosswind Displacement (Peak ACDSP)

The critical interfering locations for the total acrosswind response lie between 4b and 10b upstream and at (-3b, 4b) downstream, since the max IF lie in this range and yield the peak ALDSP. Observations show that max IF lie between 2.1 and 8.5 which is nearly equal to 2.5 and 10.0, obtained experimentally. On the downstream side slightly lower IFs are observed. On the downstream side both max IF and maximum model response occur at (-3b,4b) position.

(d) Peak Acrosswind Acceleration (Peak ACACN)

The critical interfering locations for the total acrosswind response lie between 1b and 10b upstream and at (-3b, 4b) downstream, since the max IF lie in this range and yield the peak ACACN. Observations show that max IF lie between 5.0 and 10.0 which is nearly equal to 5.2 and 10.5. On the downstream side slightly lower IFs are observed. On the downstream side both max IF and maximum model response occur at (-3b,4b) position.

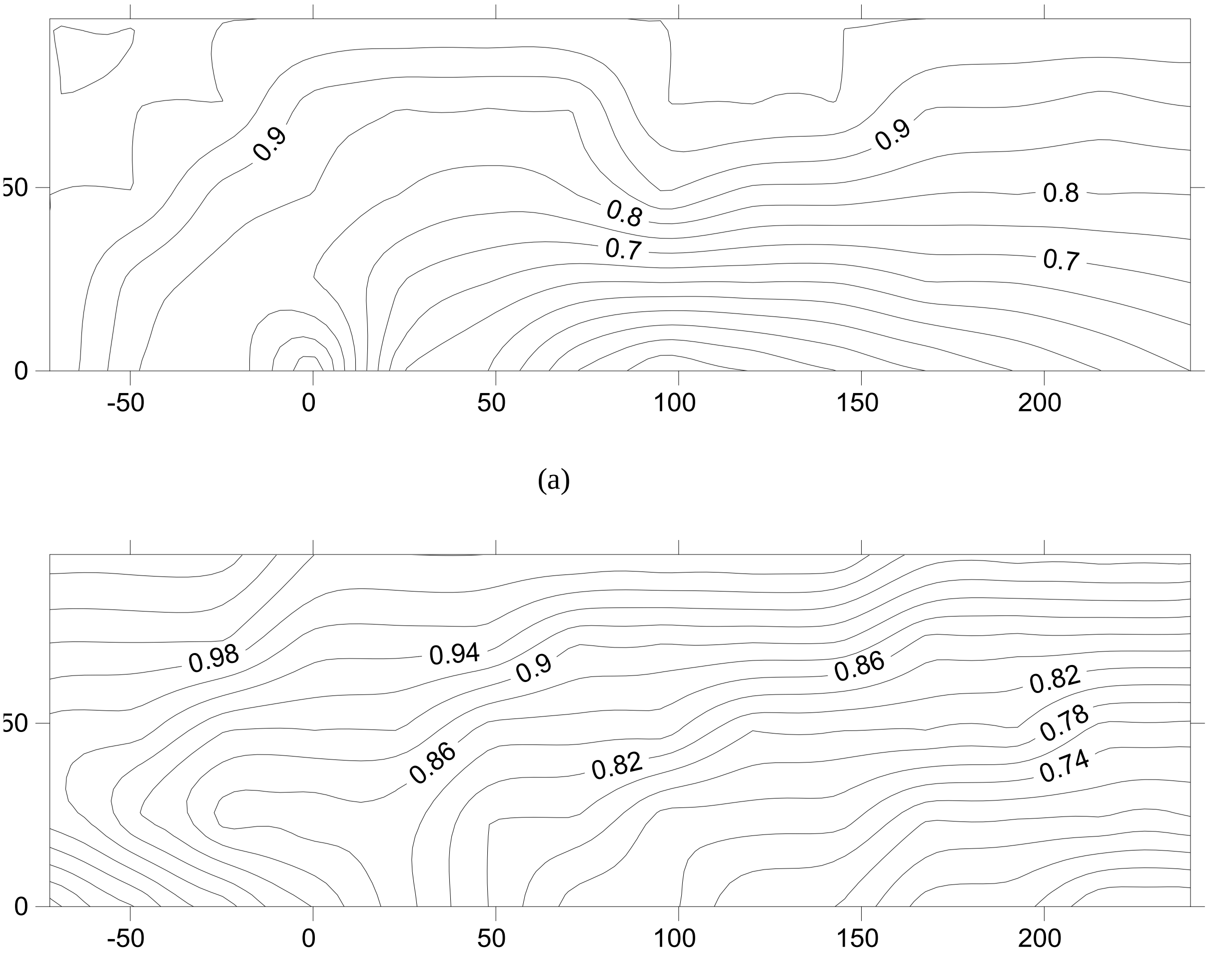
4.4 Comparison of GP results and Experimental results

The equations of IF obtained by GP for various output parameters are presented in Table 4.2.The values of IF obtained from these equations are compared with the experimental values using Contours Maps. Contour showing the comparison of the IF coefficients obtained by GP and the experimental values are presented in fig. 4.2 to 4.33 along with the Correlation Plot between Experimental and GP values. It can be observed from these contour maps that the predicted values are more or less matching with the corresponding experimental values. From the comparisons, the maximum error for any IF is observed to be 28.57%.

Table-4.2 Equations of IF obtained by GP for various parameters

Output Parameter	**Equation obtained by GP**
Mean ALDSP	$\left\{(1+\frac{Y}{H})-\left[\frac{B(2B+5Y+R_v+X+1)}{HY+2BH+XD}\right]\right\}$
Max ALDSP	$\left\{1-\frac{\left(BR_v-Y-2R_v-\frac{2R_vB^2}{H+X}-\frac{2H+X+D}{R_v}\right)}{R_v(2B+R_v+Y)}\right\}$
Peak ACDSP	$\left\{\frac{R_v-\left[\frac{D+2R_v-X-\left(\frac{H}{D+Y}\right)+Y}{R_v+2D+Y+D^2-DB}\right]}{D}\right\}$
Peak ACACN	$\left\{\frac{BR_v-X-H+\left[\frac{\left(\frac{2.29HD}{R_v}\right)-\left(\frac{XY+YH-1.85HX}{B}\right)}{R_v}\right]}{BR_v}\right\}$

** B, D, & H- Geometric Dimensions, R_V- Reduced Velocity, X & Y – Distance from test building.



(a)

(b)

Fig.4.2 Comparison of IF obtained by (a) experiment and (b) predicted by GP for Mean ALDSP RV = 6.03 with R1 interfering building

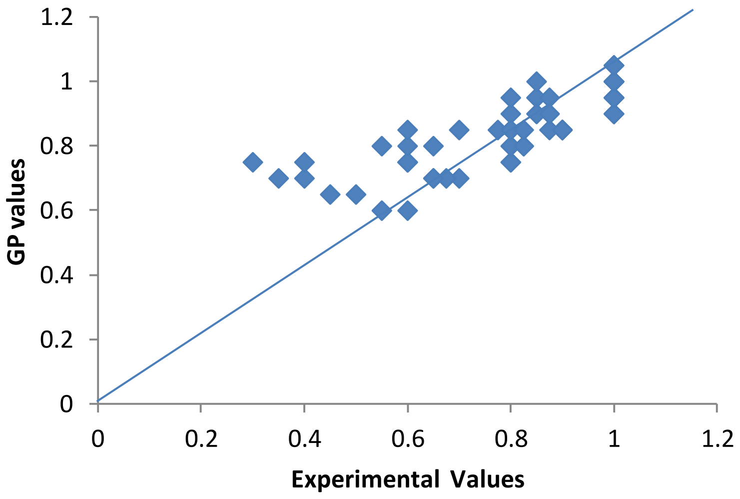
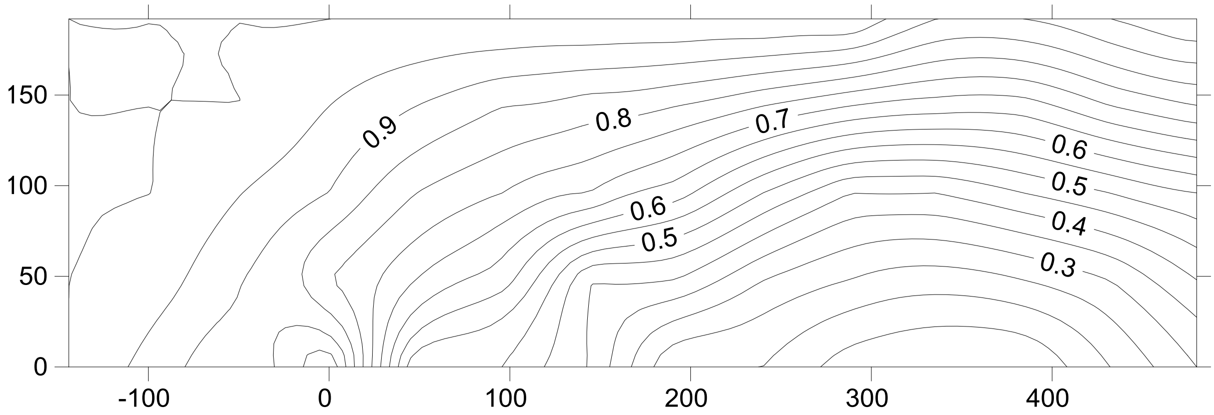
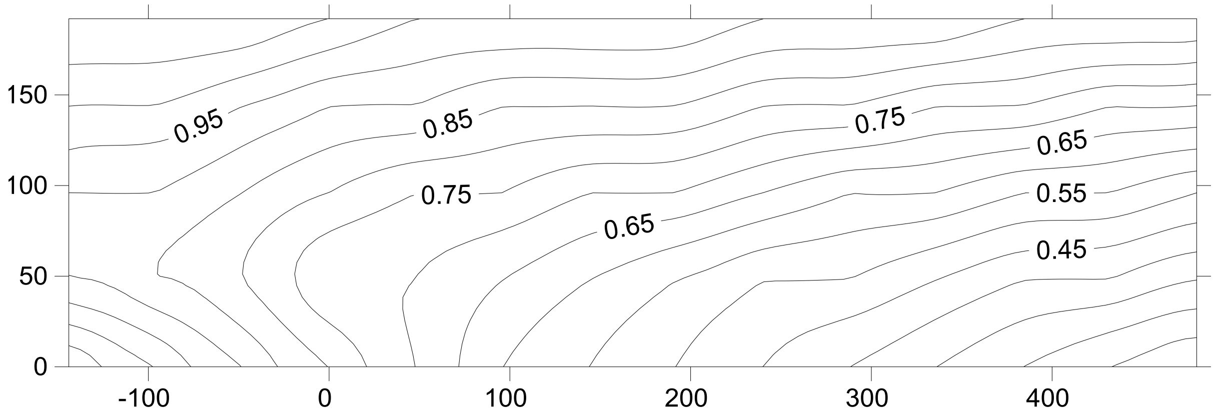


Fig.4.3 Correlation Plot between Experiment and predicted GP values for Mean ALDSP RV = 6.03 with R1 interfering building



(a)



(b)

Fig.4.4 Comparison of IF obtained by (a) experiment and (b) predicted by GP for Mean ALDSP RV = 6.03 with R2 interfering building

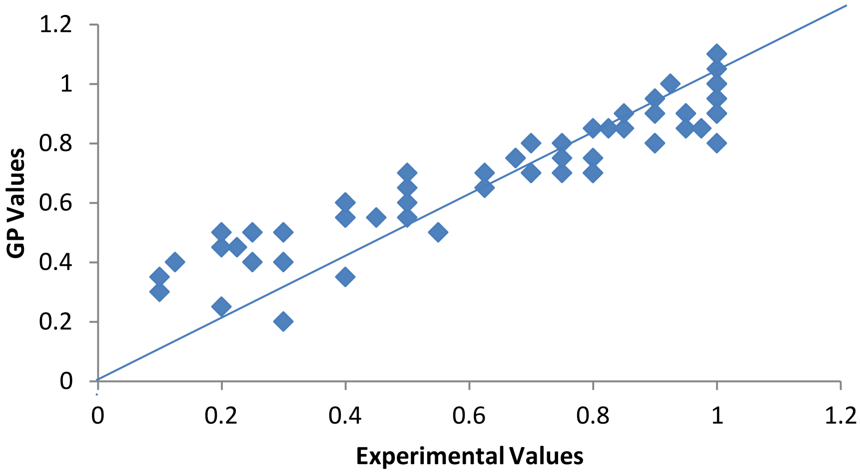
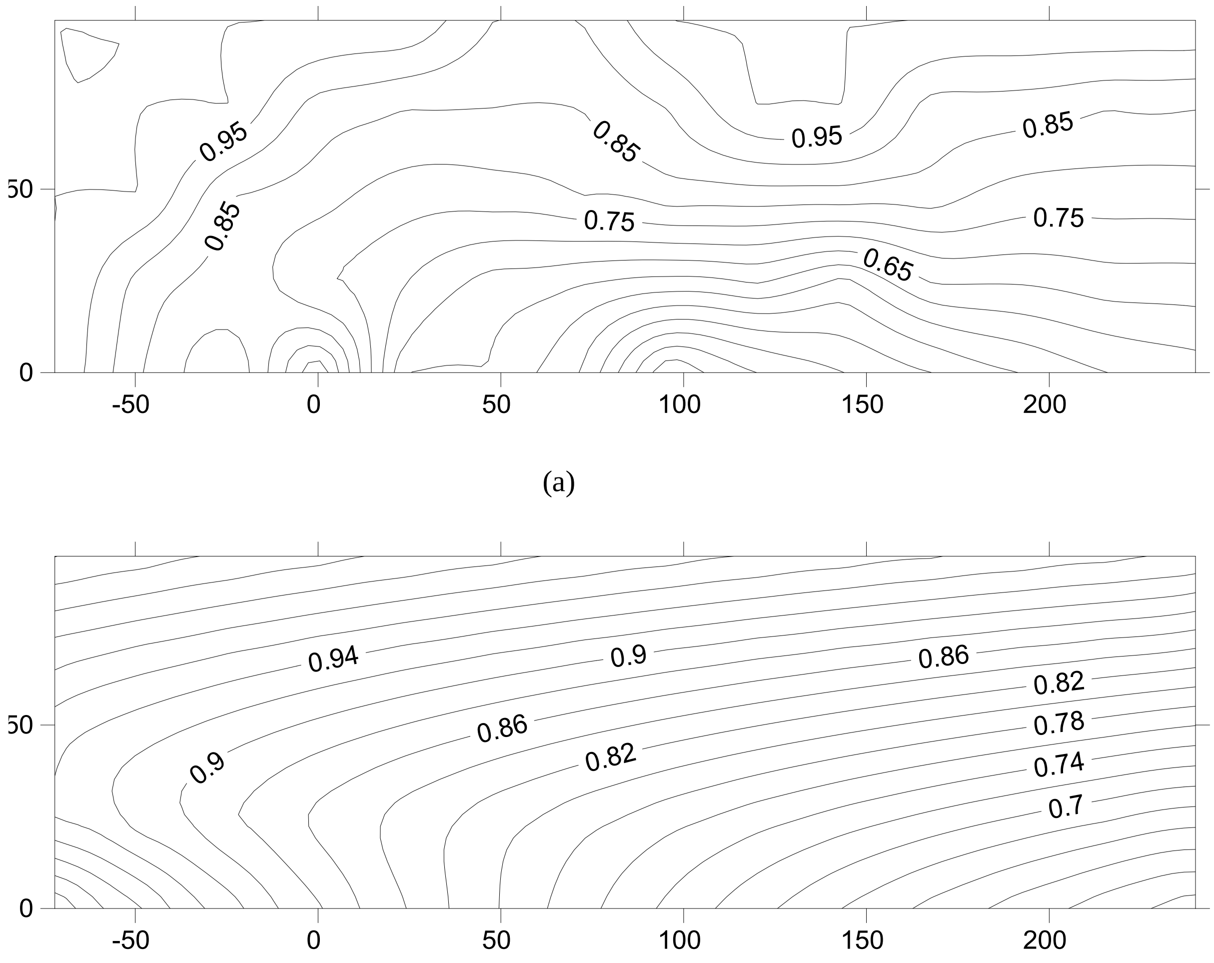


Fig.4.5 Correlation Plot between Experiment and predicted GP values for Mean ALDSP RV = 6.03 with R2 interfering building



(a)

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Fig.4.6 Comparison of IF obtained by (a) experiment and (b) predicted by GP for Mean ALDSP RV = 7.30 with R1 interfering building

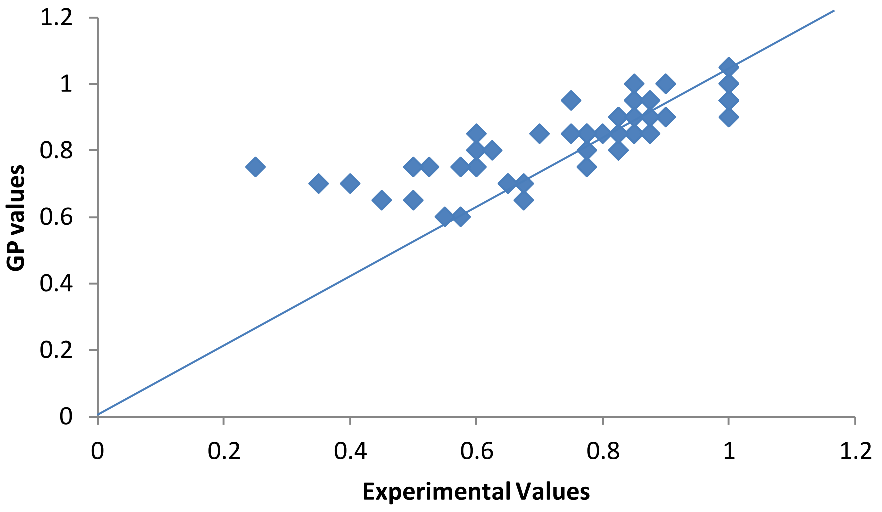
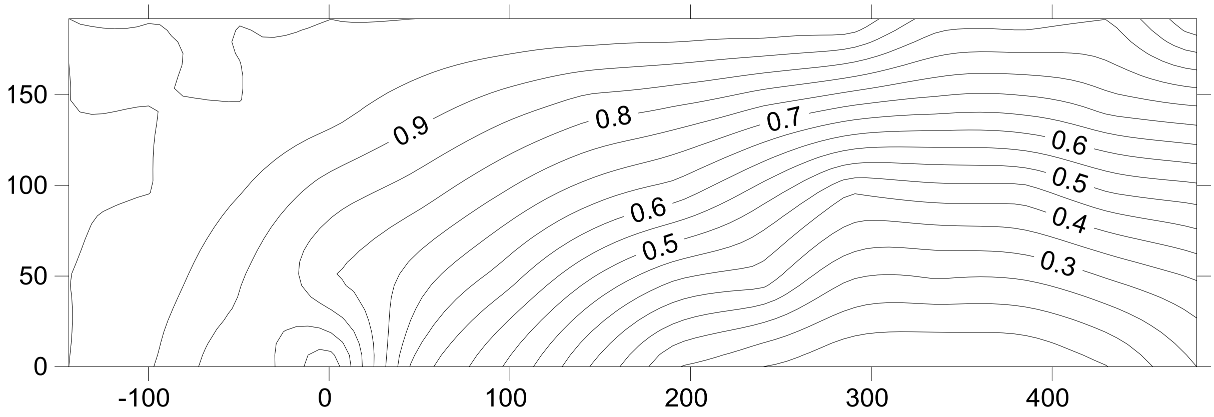
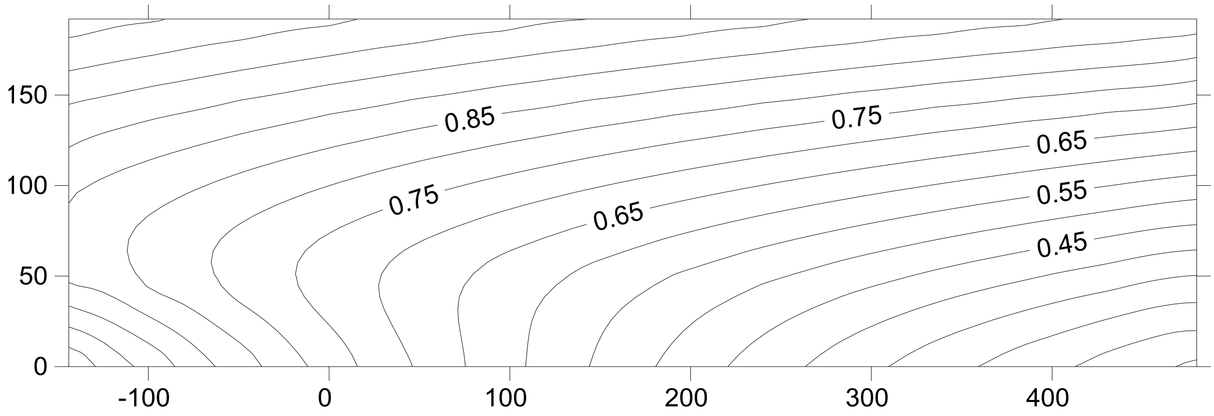


Fig.4.7 Correlation Plot between Experiment and predicted GP values for Mean ALDSP RV = 7.30 with R1 interfering building



(a)



(b)

Fig.4.8 Comparison of IF obtained by (a) experiment and (b) predicted by GP for Mean ALDSP RV = 7.30 with R2 interfering building

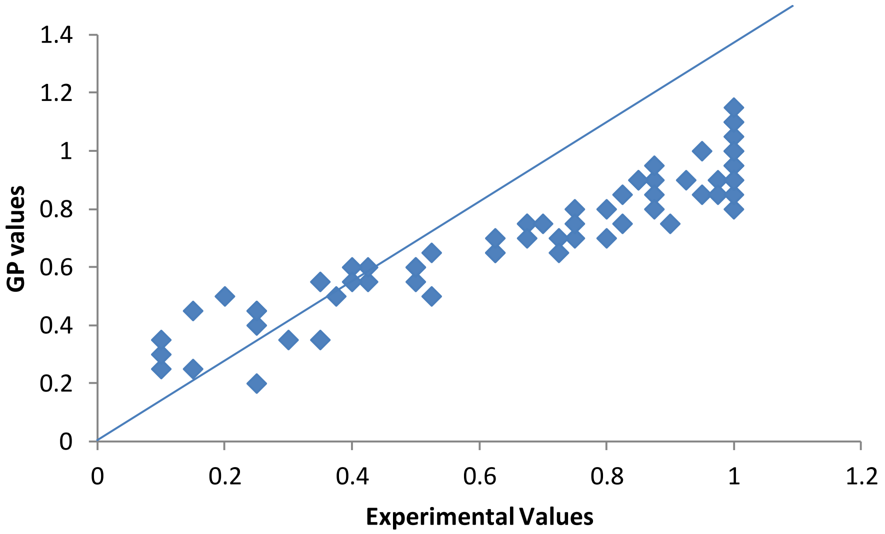
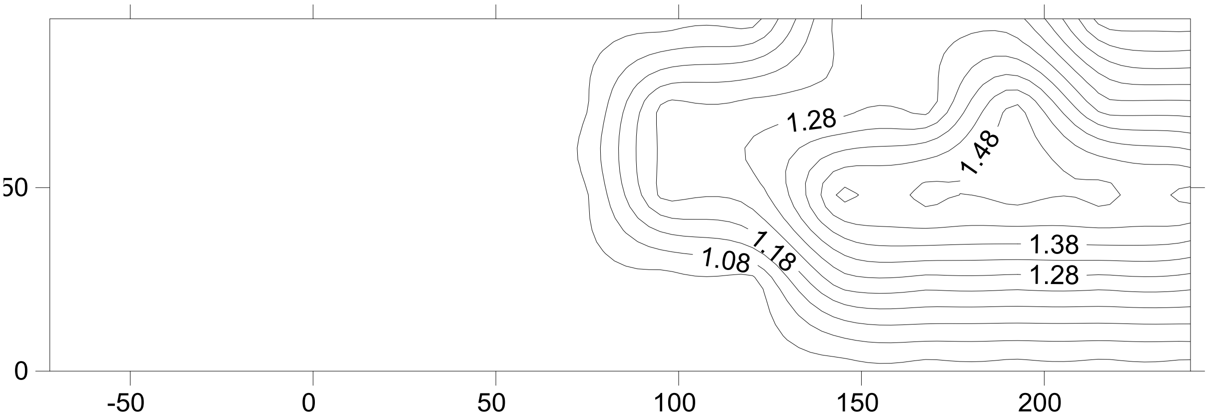
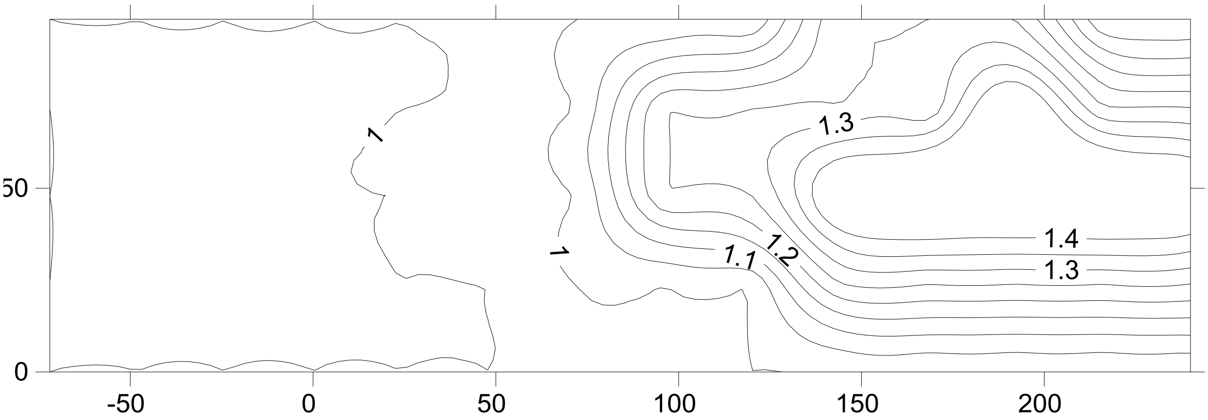


Fig.4.9 Correlation Plot between Experiment and predicted GP values for Mean ALDSP RV = 7.30 with R2 interfering building



(a)



(b)

Fig.4.10 Comparison of IF obtained by (a) experiment and (b) predicted by GP for Max ALDSP RV = 6.03 with R1 interfering building

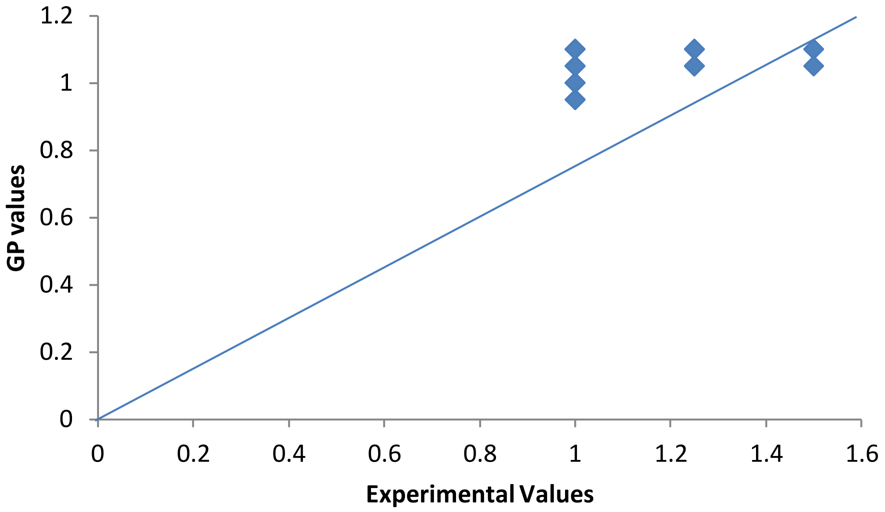
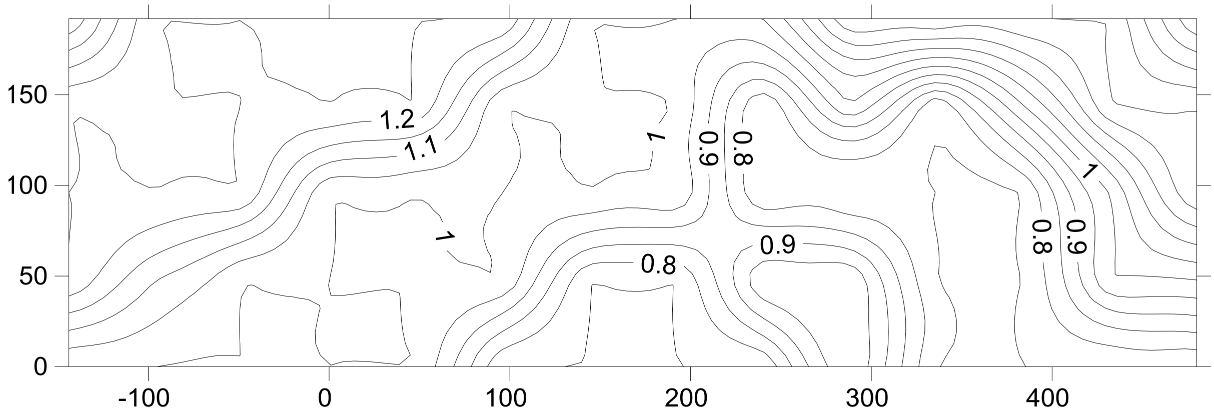


Fig.4.11 Correlation Plot between Experiment and predicted GP values for Max ALDSP RV = 6.03 with R1 interfering building



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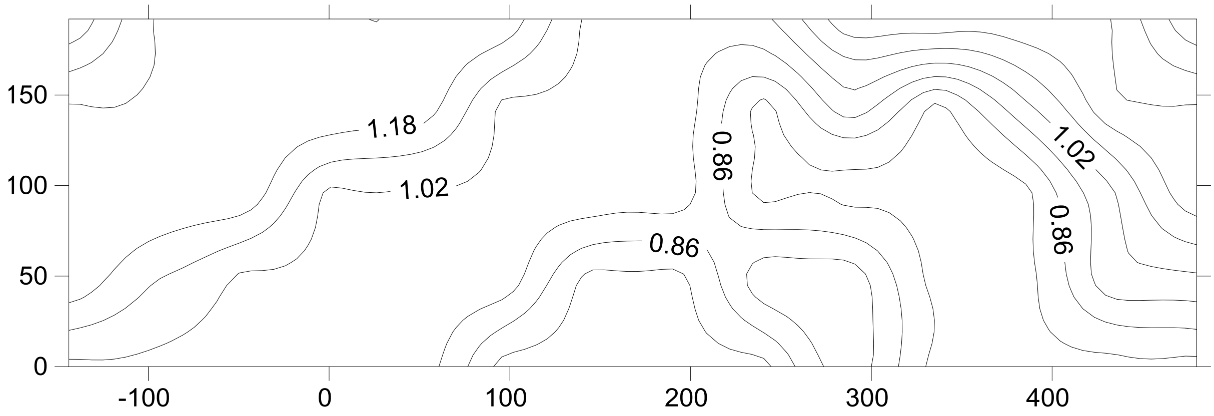


(b)

Fig.4.12 Comparison of IF obtained by (a) experiment and (b) predicted by GP for Max ALDSP RV = 6.03 with R2 interfering building

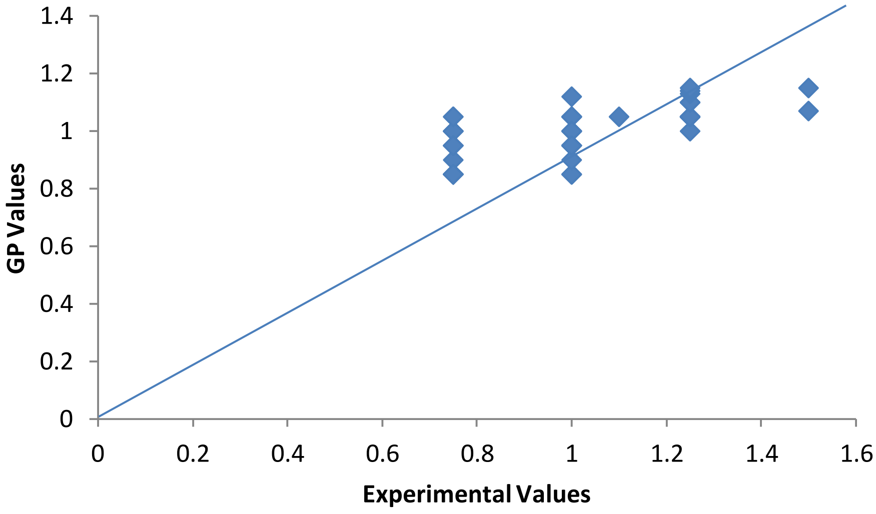
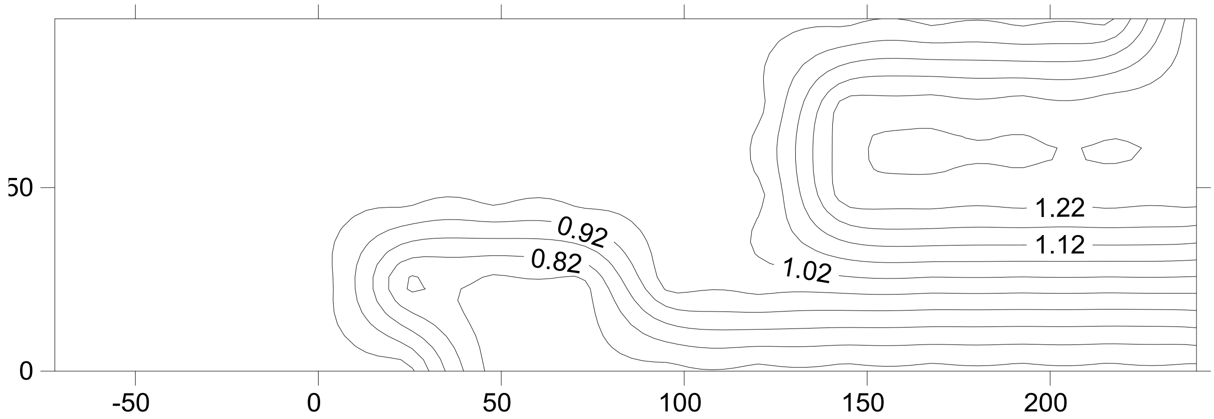
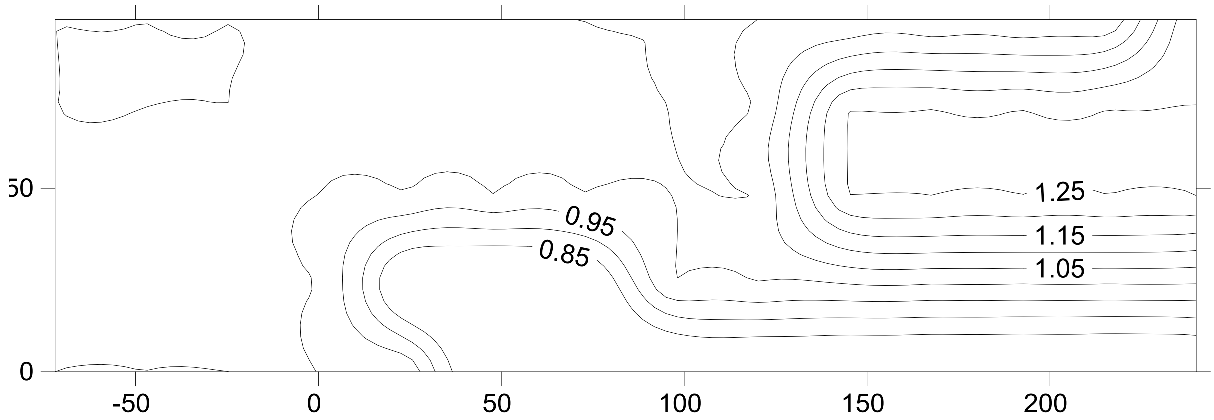


Fig.4.13 Correlation Plot between Experiment and predicted GP values for Max ALDSP RV = 6.03 with R2 interfering building



(a)



(b)

Fig.4.14 Comparison of IF obtained by (a) experiment and (b) predicted by GP for Max ALDSP RV = 7.30 with R1 interfering building

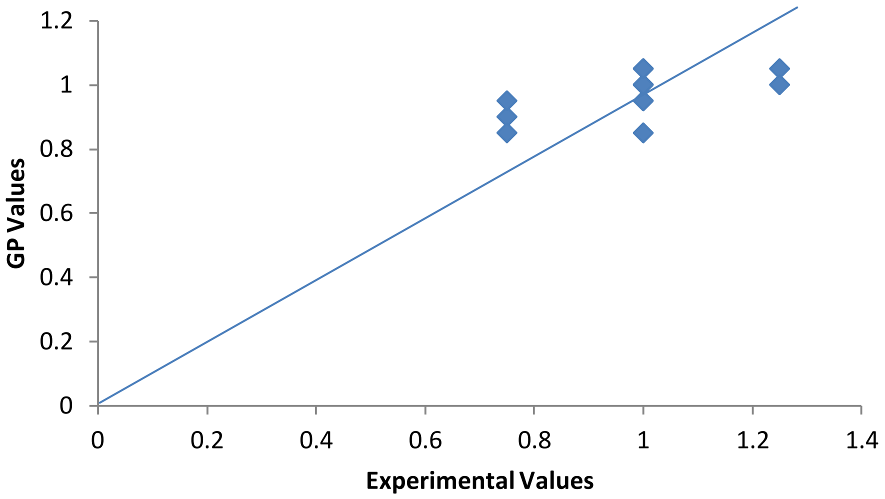
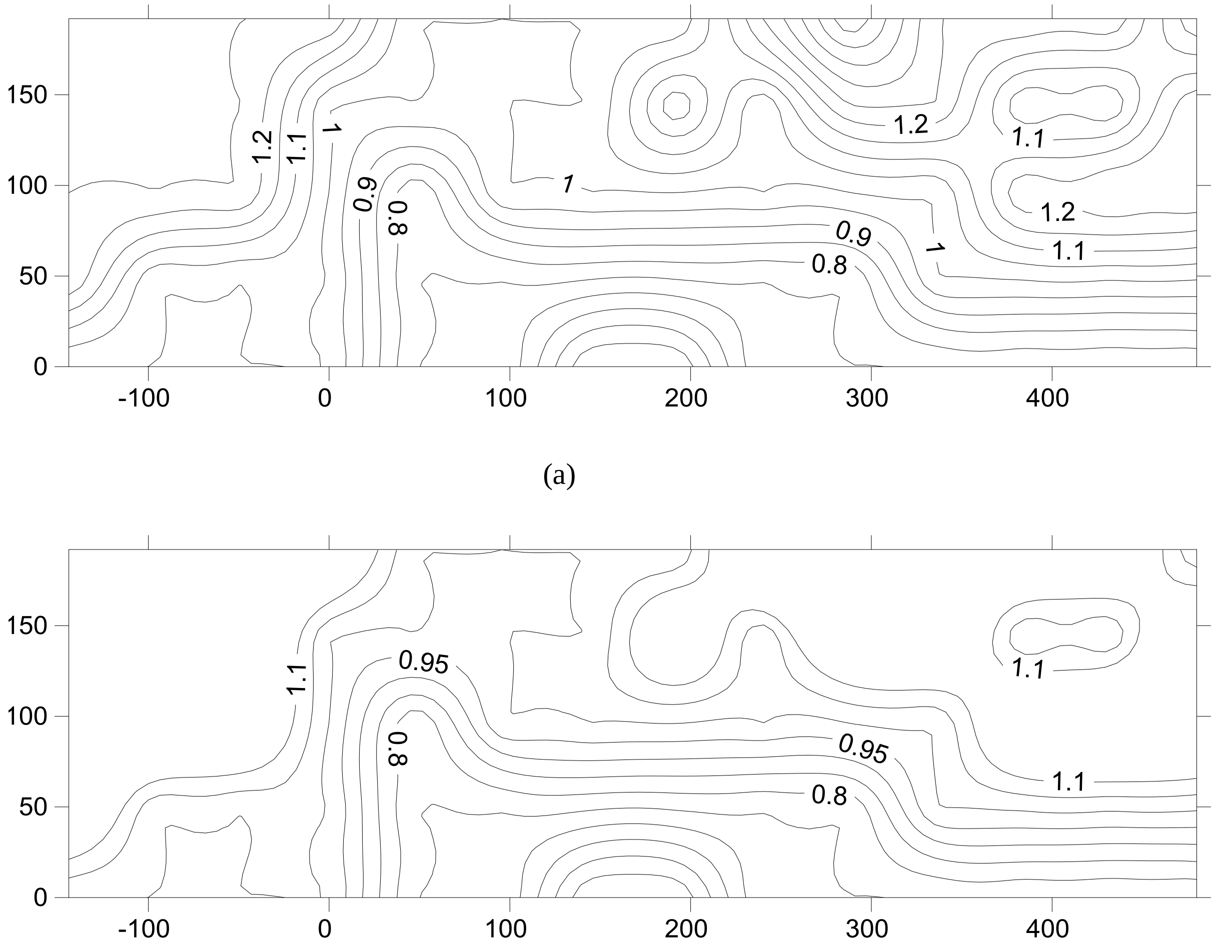


Fig.4.15 Correlation Plot between Experiment and predicted GP values for Max ALDSP RV = 7.30 with R1 interfering building



(a)

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Fig.4.16 **Comparison of IF obtained by (a) experiment and (b) predicted by GP for Max ALDSP RV = 7.30 with R2 interfering building**

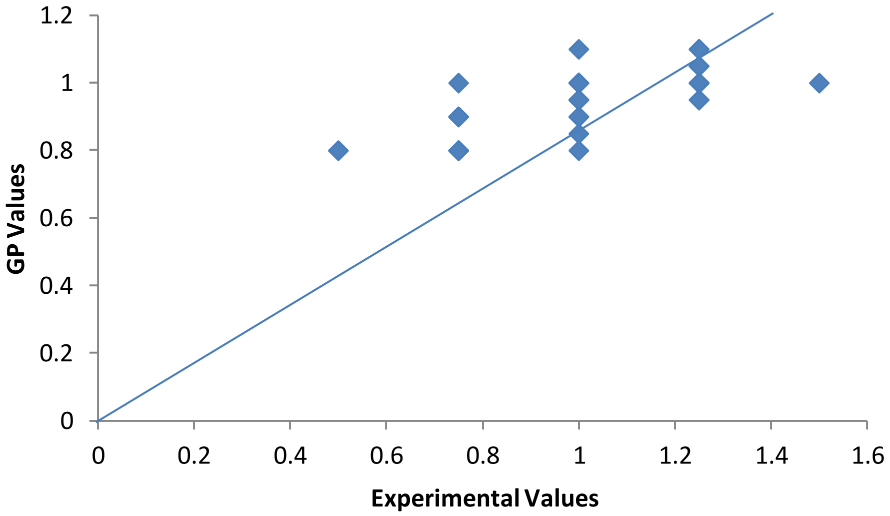
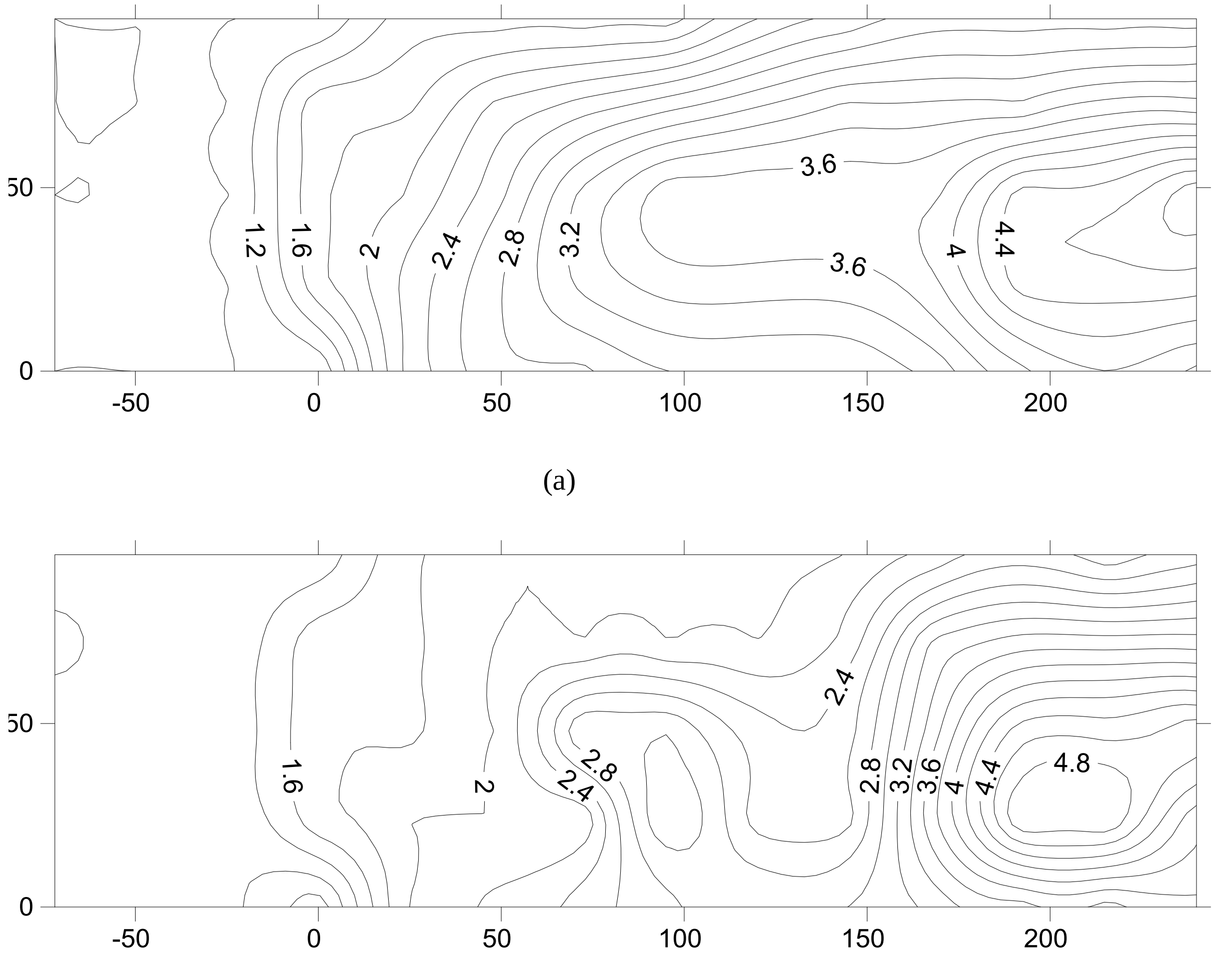


Fig.4.17 Correlation Plot between Experiment and predicted GP values for Max ALDSP RV = 7.30 with R2 interfering building



(a)

(b)

Fig.4.18 Comparison of IF obtained by (a) experiment and (b) predicted by GP for Peak ACDSP RV = 4.86 with R1 interfering building

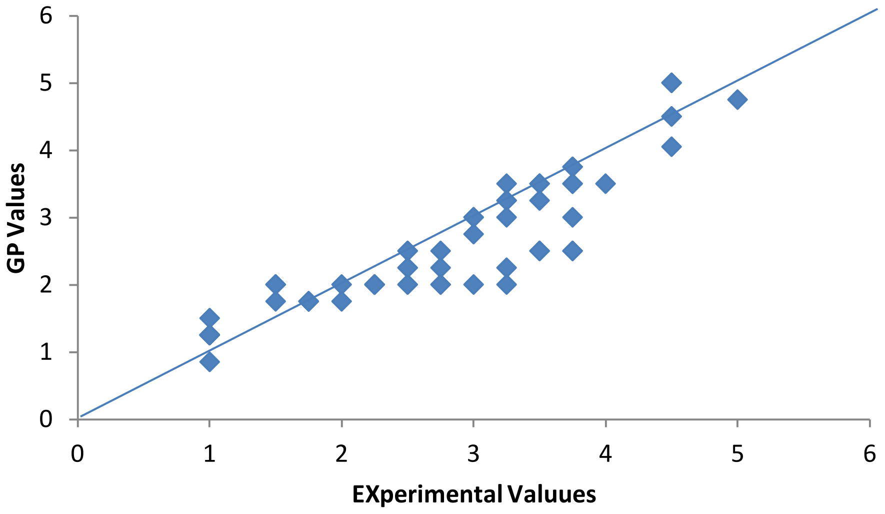
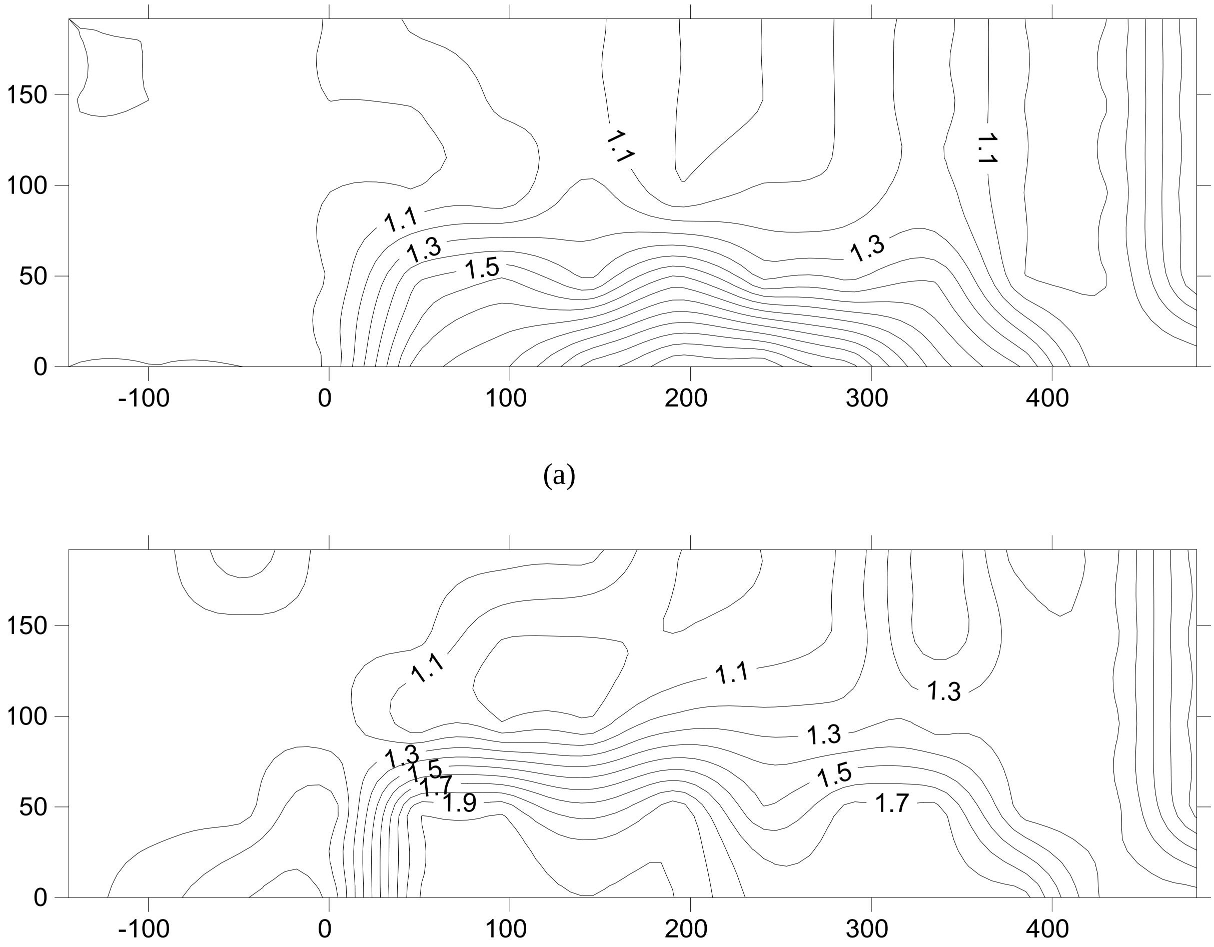


Fig.4.19 Correlation Plot between Experiment and predicted GP values for Peak ACDSP RV = 4.86 with R1 interfering building



(a)

(b)

Fig.4.20 Comparison of IF obtained by (a) experiment and (b) predicted by GP for Peak ACDSP RV = 4.86 with R2 interfering building

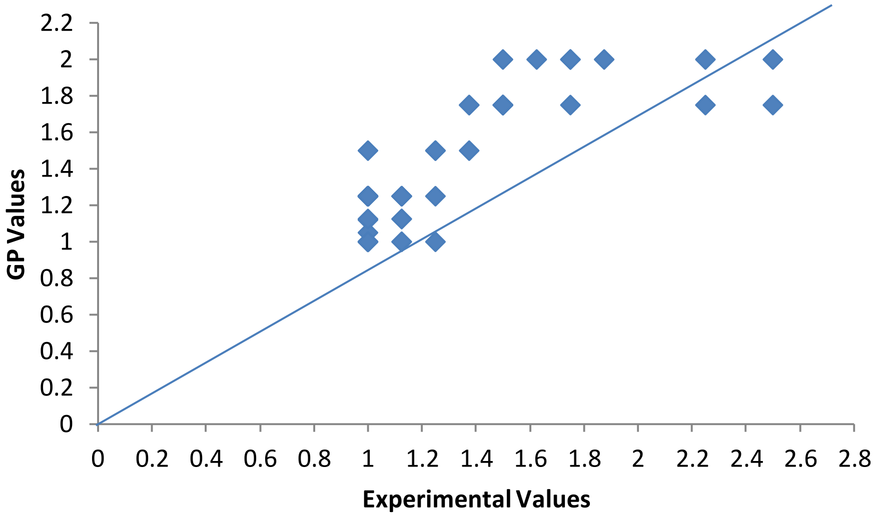
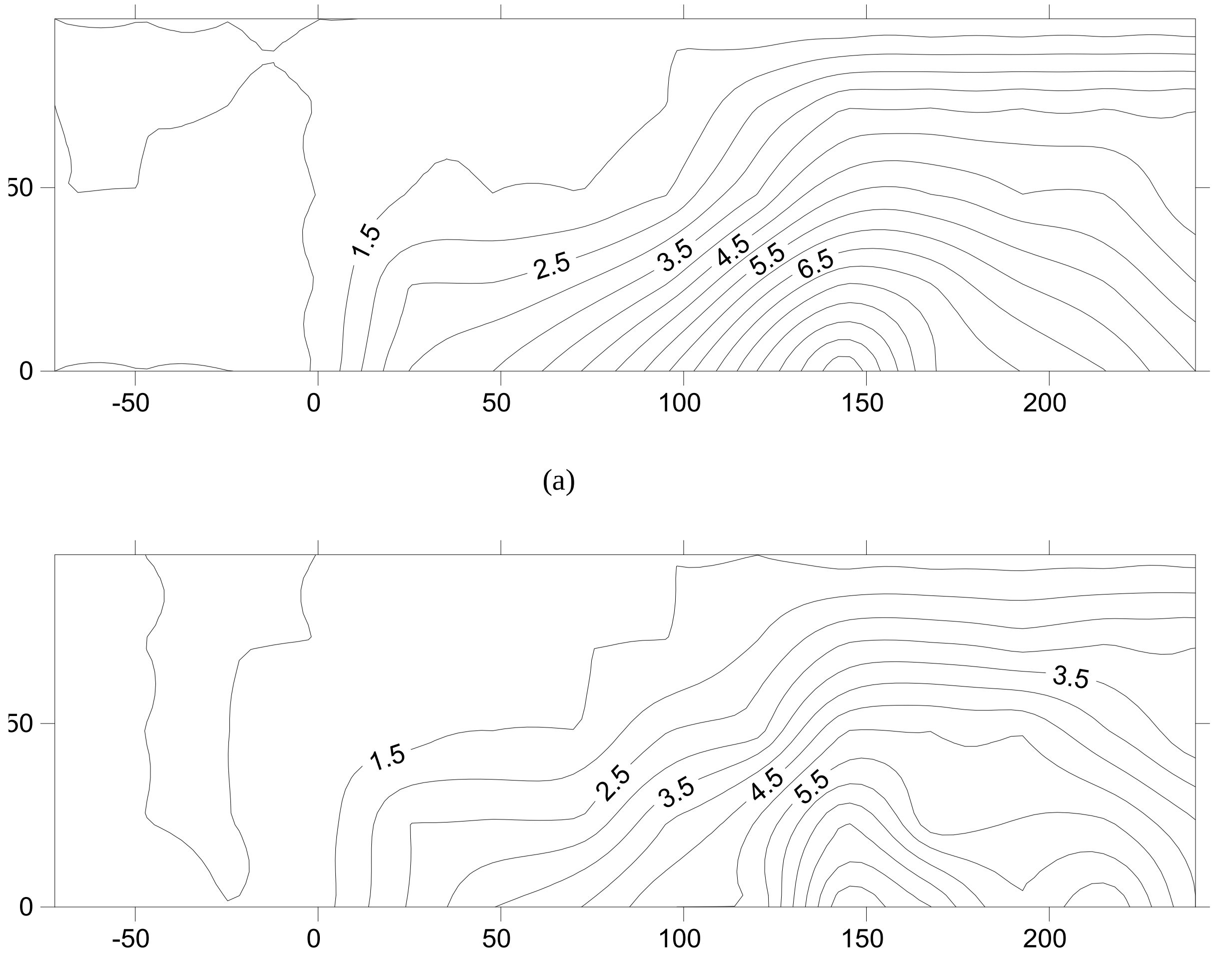


Fig.4.21 Correlation Plot between Experiment and predicted GP values for Peak ACDSP RV = 4.86 with R2 interfering building



(a)

(b)

Fig.4.22 Comparison of IF obtained by (a) experiment and (b) predicted by GP for Peak ACDSP RV = 5.88 with R1 interfering building

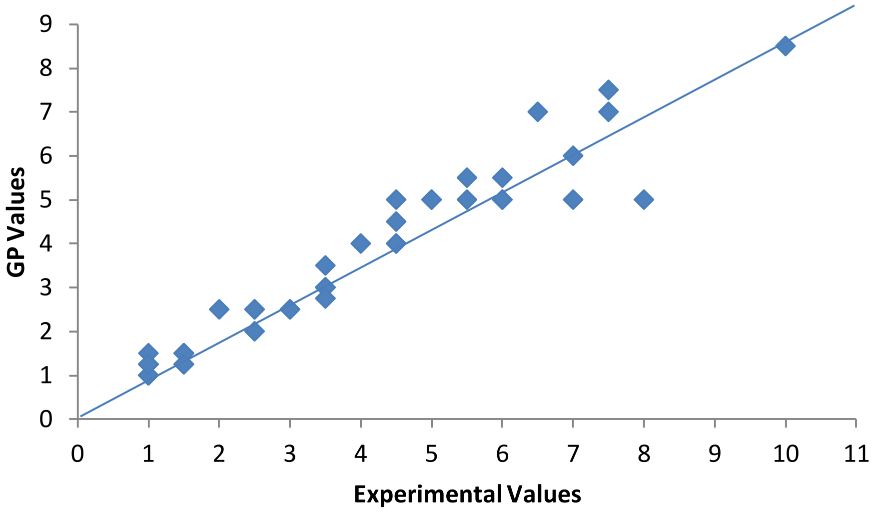
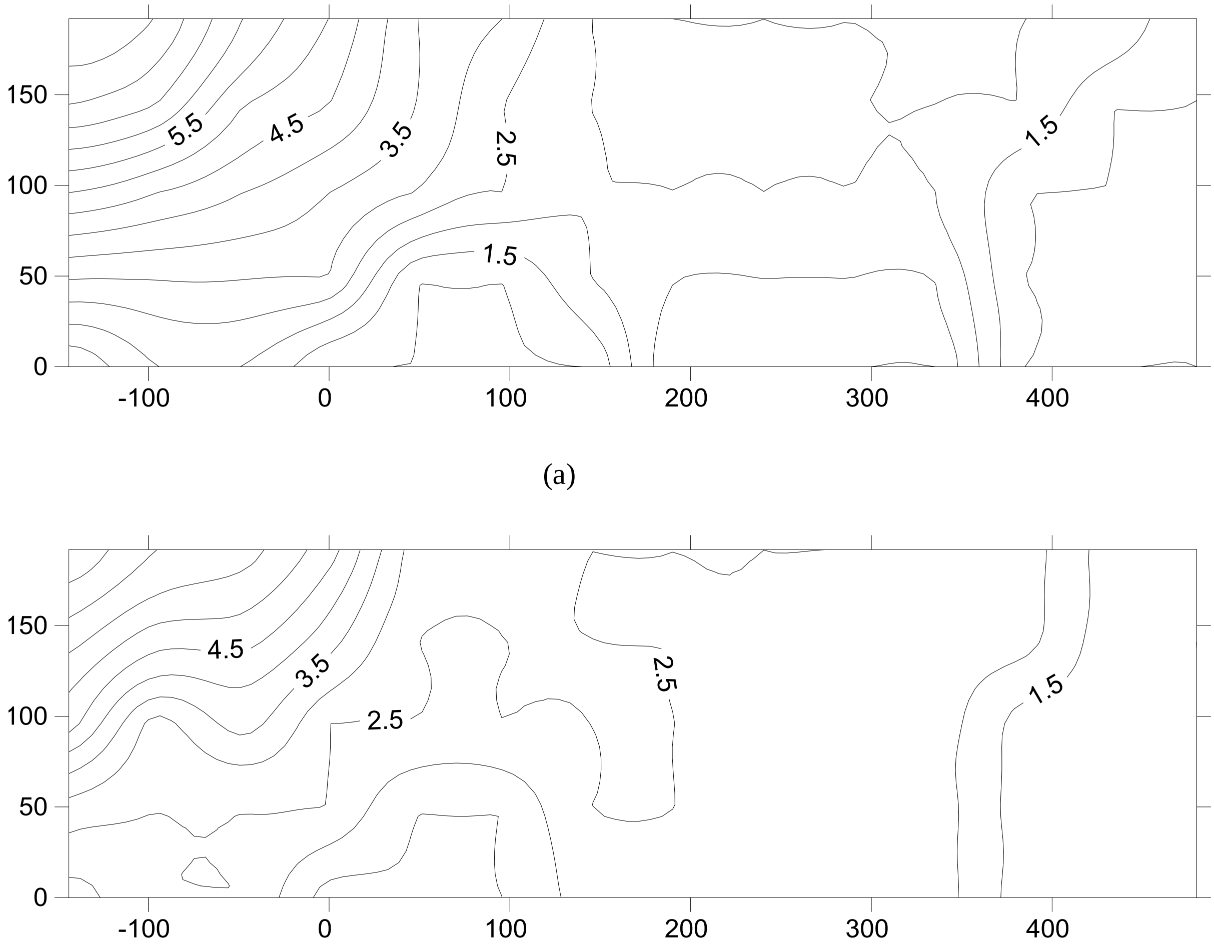


Fig.4.23 Correlation Plot between Experiment and predicted GP values for Peak ACDSP RV = 5.88 with R1 interfering building



(a)

(b)

Fig.4.24 Comparison of IF obtained by (a) experiment and (b) predicted by GP for Peak ACDSP RV = 5.88 with R2 interfering building

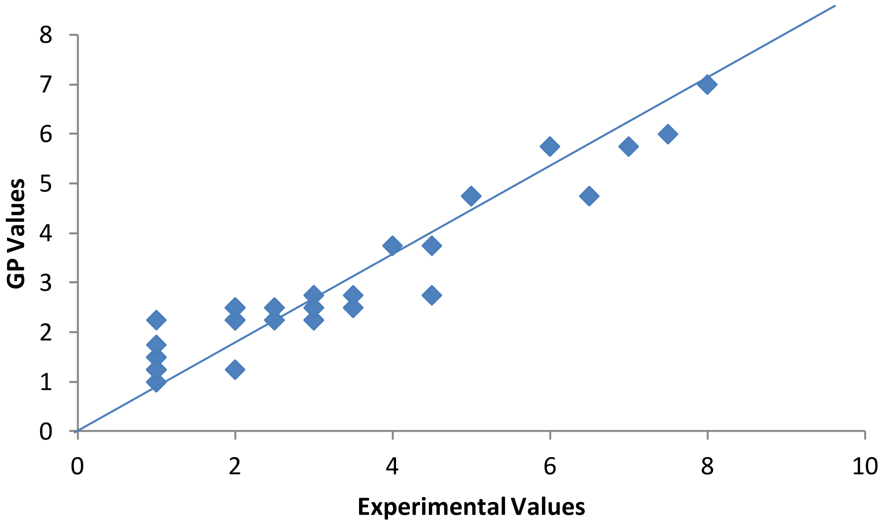


Fig.4.25 Correlation Plot between Experiment and predicted GP values for Peak ACDSP RV = 5.88 with R2 interfering building

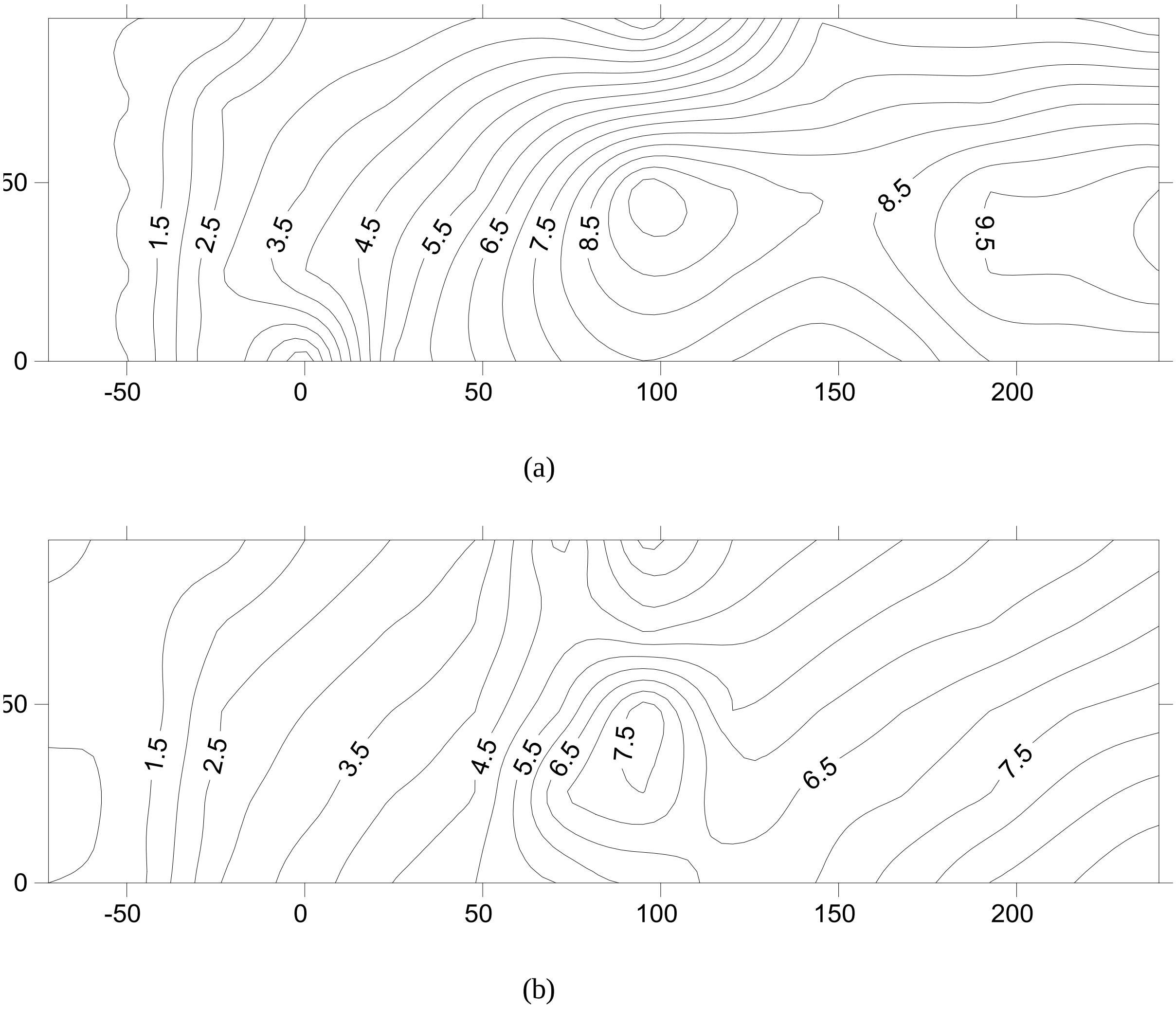


Fig.4.26 Comparison of IF obtained by (a) experiment and (b) predicted by GP for Peak ACACN RV = 4.86 with R1 interfering building

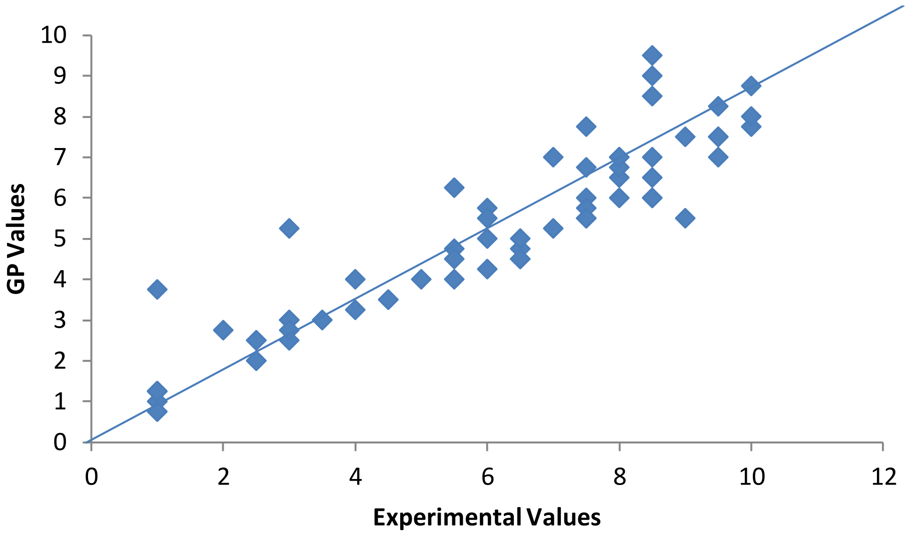
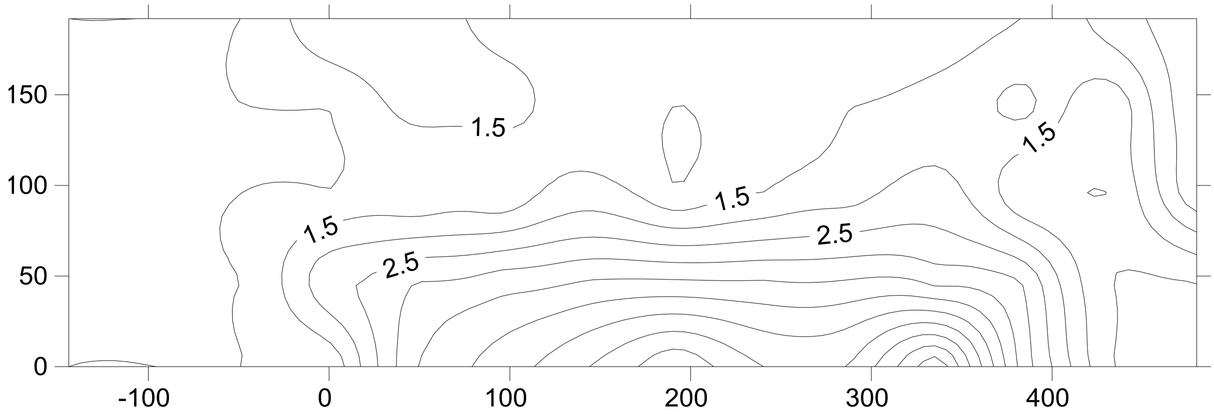
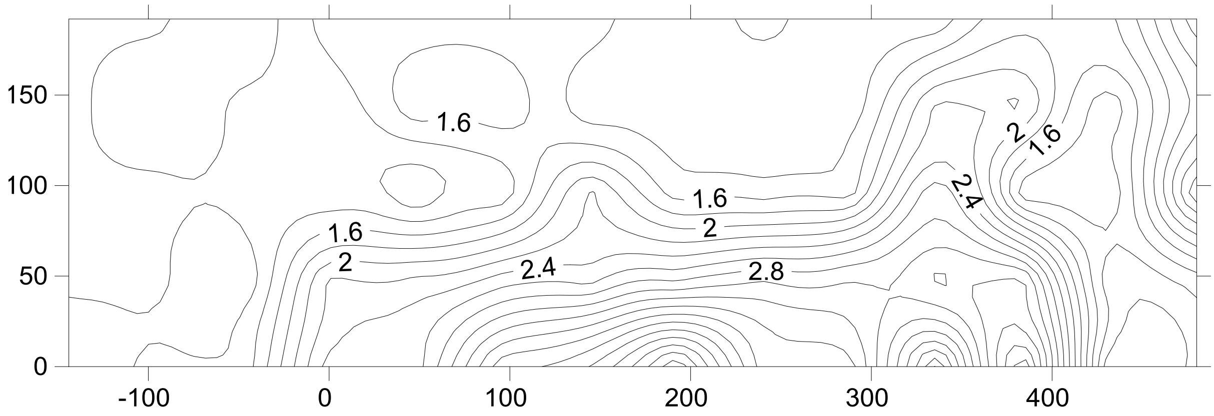


Fig.4.27 Correlation Plot between Experiment and predicted GP values for Peak ACACN RV = 4.86 with R1 interfering building



(a)



(b)

Fig.4.28 Comparison of IF obtained by (a) experiment and (b) predicted by GP for Peak ACACN RV = 4.86 with R2 interfering building

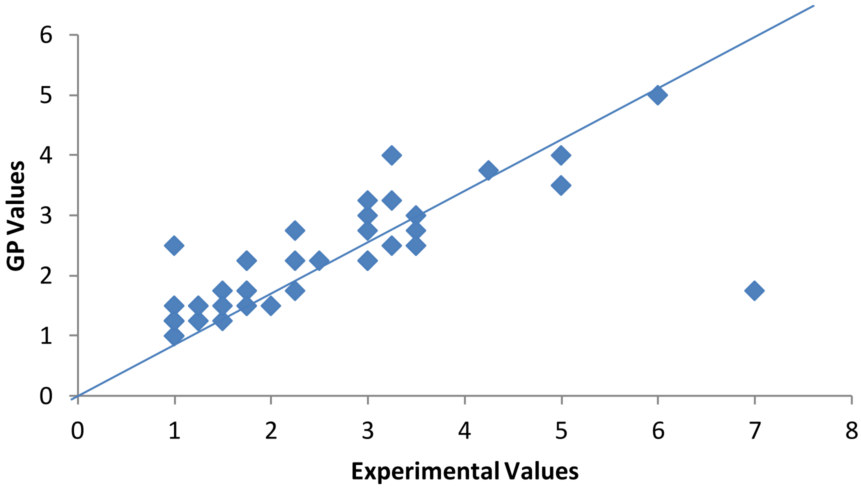
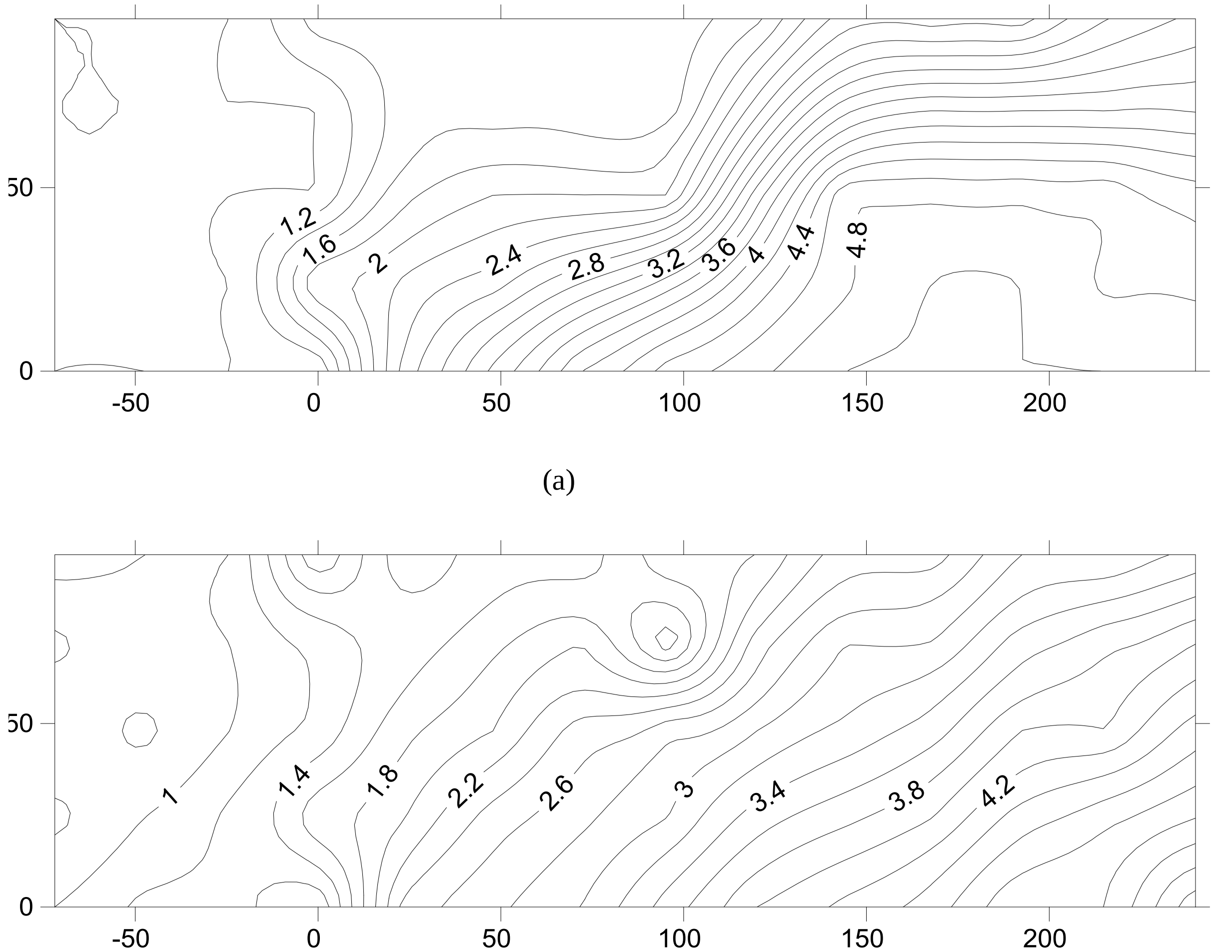


Fig.4.29 Correlation Plot between Experiment and predicted GP values for Peak ACACN RV = 4.86 with R2 interfering building



(a)

(b)

Fig.4.30 Comparison of IF obtained by (a) experiment and (b) predicted by GP for Peak ACACN RV = 5.88 with R1 interfering building

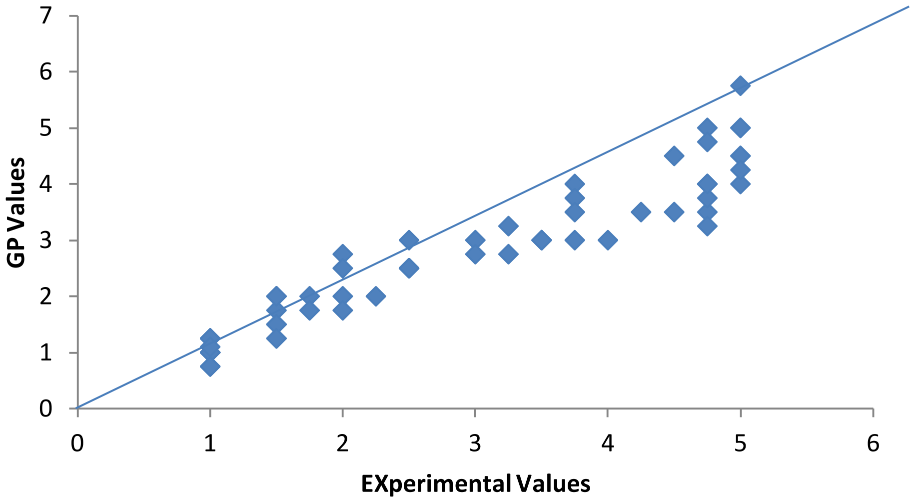
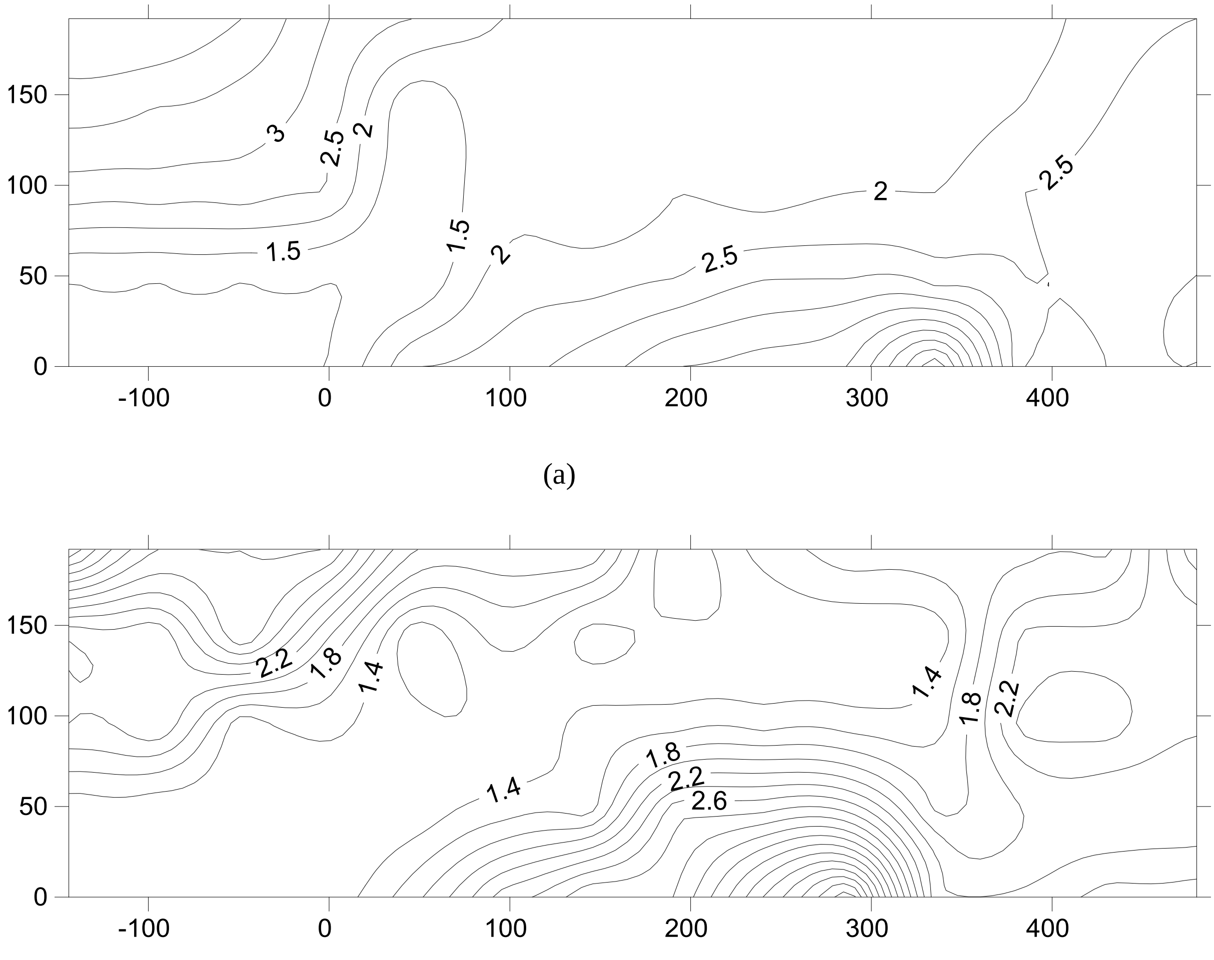


Fig.4.31 Correlation Plot between Experiment and predicted GP values for Peak ACACN RV = 5.88 with R1 interfering building



(a)

(b)

Fig.4.32 Comparison of IF obtained by (a) experiment and (b) predicted by GP for Peak ACACN RV = 5.88 with R2 interfering building

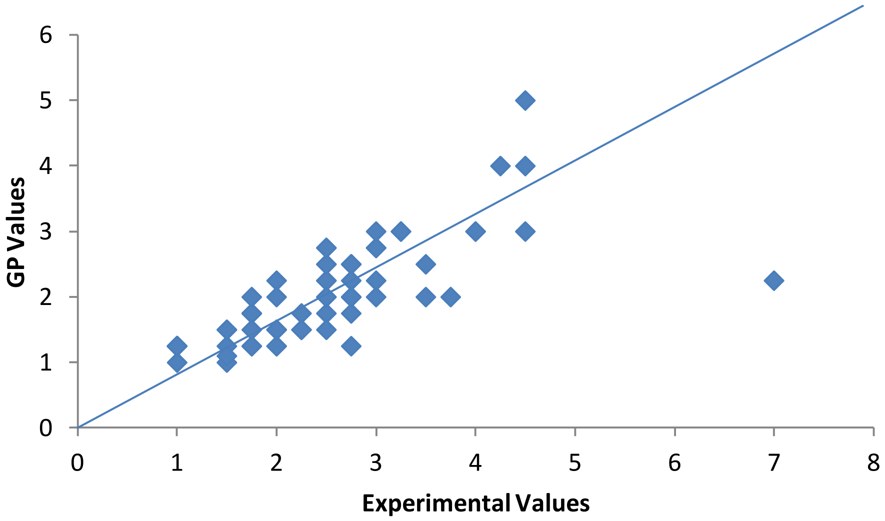


Fig.4.33 Correlation Plot between Experiment and predicted GP values for Peak ACACN RV = 5.88 with R2 interfering building

CHAPTER – 5

CONCLUSIONS

5.1 General

This present study has been conducted to study the application of Genetic Programming for the determination of Interference Factor (IF) between various output parameters tall buildings.

As a first step of the study, database has been taken from the experimental study caried out by Gupta(1996). Thereafter, equations have been developed for IFs using Genetic Programming for Mean ALDSP, Max ALDSP, Peak ACDSP and Peak ACACN. The IF thus obtained from these equations have been compared with the experimental data. It can be observed from these contour maps that the predicted values are more or less matching with the corresponding experimental values and fairly describe the behaviour of a tall building with maximum error in any of the IF factor as 28.57%. Interference being a complex phenomenon and in the absence of any analytical solution to the problem, the error is considered to be fairly reasonable. The results thus obtained can be used by the designers for preparation of Wind Tunnel Experimental setup, although the exact values are to be ascertained only after wind tunnel experiment.

5.2 Main Conclusions

- The main conclusion drawn from this study is that the Genetic Programming is seen to predict successfully the IF for tall buildings and results obtained are fairly matching with the experimental data taken from study carried out by Gupta(1996). The range of percentage error observed in maximum Mean ALDSP obtained from GP to experimental value is 0.95 to 9.5%, for maximum Max ALDSP percentage error is 2.58 to 26.6%, for maximum Peak ACDSP percentage error is 3.8 to 16% and for maximum Peak ACACN percentage error is 4.76 to 28.57%.
- The Genetic Programming has been used as a tool to acquire equation for such a complex phenomenonon like Interfernce for tall buildings successfully, thus reducing the laborious work involved in their estimation through wind tunnel testing. Therefore the GP can be used for any kind of database available for any problem.

REFRENCES

Koza, J.R, (1992), Genetic Programming on the programming of computers by means of natural selection, A Bradford book, MIT press.

Z.N. Xie a,b, M. Gua(2004), Mean interference effects among tall buildings, Engineering Structures 26 (2004) 1173–1183.

Ning Lin, Chris Letchford,, Yukio Tamura, Bo Liang, Osamu Nakamura(2005), Characteristics of wind forces acting on tall buildings, Journal of Wind Engineering and Industrial Aerodynamics 93 (2005) 217–242.

Johari, A., Habibagahi, Ghahramani, A., (2006), Prediction of soil water characteristics curve using Genetic Programming, Journal of Geotechnical and Geoenvironmental Engineering, Vol. 132, No. 5, 661-665.

K.M. Lam, J.G. Zhao(2006), Interference effects of wind loads on a row of tall buildings, Fourth international symposium on computational wind engg(CWE2006), Yokohama.

Z.N. Xie a,b, M. Gua(2006), Simplified formulas for evaluation of wind-induced interference effects among three tall buildings, Journal of Wind Engineering and Industrial Aerodynamics 95 (2007) 31–52.

Heshmati, A.A.R., Salehzade, H., Alavi, A.H, Badkobeh, A, Ghasemi, A (2008), On the applicability of linear Genetic Programming for the formulation of soil classification, American-European J. Agric. & Environ. Sci., 4(5), 575-583.

Gaur, Surbhi, Deo, M.C., (2008), Real time wave forecasting using Genetic Programming, Ocean engineering, 35 (11-12), 1166-1172.

K.M. Lam_, M.Y. H. Leung, J.G. Zhao(2008), Interference effects on wind loading of a row of closely spaced tall buildings, Journal of Wind Engineering and Industrial Aerodynamics 96 (2008) 562–583.

Kermani, E., Jafarian, Y. and Bazier, M.H. (2009), New predictive models for the Vmax/Amax ratio of strong ground motion using Genetic Programming, International journal of civil engineering, Vol. 7, No. 4,236-247.

Nitsure, S.P., Londhe, S.N. and Khare, K.C. (2009), Application of Genetic Programming for estimation of ocean wave heights, Nature and biological inspired computing 2009, 1520-1523.

Wonsul Kim, Yukio Tamura and Akihito Yoshida(2009) ,Interference effects of two buildings on peak wind pressures, The Seventh Asia-Pacific Conference on Wind Engineering, November 8-12, 2009, Taipei, Taiwan

Saridemir, M. (2010), Genetic Programming approach for prediction of compressive strength of concrete containg rice husk ash, Journal: construction and building material, Vol. 24, No. 10, 1911-1919.

Ning Han a, Ming Gu a, Peng Huang a(2012), Interference effect on wind pressure of two buildings The Seventh International Colloquium on Bluff Body Aerodynamics and Applications (BBAA7) Shanghai, China; September 2-6, 2012.

Muduli, P.K., Das, S.K. (2013), CPT- based seismic liquefaction potential evaluation using multi-gene Genetic Programming approach, Indian Geotechnical Journal.

Tang Yia Jin Xinyanga Yang Liguoa(2012), Research on interference effects of wind loads on tall buildings in staggered arrangement, The Seventh International Colloquium on Bluff Body Aerodynamics and Applications (BBAA7) Shanghai, China; September 2-6, 2012.

Yi Hui n, Yukio Tamura, Akihito Yoshida(2012), Mutual interference effects between two high-rise building models with different shapes on local peak pressure coefficients, J. Wind Eng. Ind. Aerodyn. 104–106 (2012) 98–108.

Divya Aggarwal, Naveen Kwatra, (2013), Application of genetic programming for determination of wind loads on tall buildings, The Eighth Asia-Pacific Conference on Wind Engineering, December 10-14, 2013, Chennai, India.

Feng Wang a,b,n, Yukio Tamura b, Akihito Yoshida b(2013), Interference effects of a neighboring building on wind loads on scaffolding, J. WindEng.Ind.Aerodyn.125(2014)1–12.

Steven J .Daniels, Ian P. Castro, Zheng -Tong Xie (2013), Peak loading and surface pressure fluctuations of a tall model building, J. Wind Eng .Ind.Aerodyn.120(2013)19–28..

Yi Hui n, Akihito Yoshida, Yukio Tamura (2013),Interference effects between two rectangular-section high-rise buildings on local peak pressure coefficients, Journal of Fluids and Structures 37 (2013) 120–133.

Appendix to Chapter 4 Para 4.3

Table-4.3 Table showing the Input and Output Parameters used and results obtained using GP for Mean ALDSP

B	D	H	R_v	X	Y	MEANALDSP EXPERIMENTAL VALUES	GP OBTAINED VALUES
24	24	240	6.03	240	0	0.6	0.590236
24	24	240	6.03	240	24	0.7	0.667677
24	24	240	6.03	240	48	0.8	0.754142
24	24	240	6.03	240	72	0.9	0.845118
24	24	240	6.03	240	96	1	0.938673
24	24	240	6.03	216	0	0.55	0.610589
24	24	240	6.03	216	24	0.675	0.682233
24	24	240	6.03	216	48	0.8	0.765451
24	24	240	6.03	216	72	0.875	0.854357
24	24	240	6.03	216	96	1	0.946479
24	24	240	6.03	192	0	0.5	0.632396
24	24	240	6.03	192	24	0.65	0.697555
24	24	240	6.03	192	48	0.8	0.777231
24	24	240	6.03	192	72	0.9	0.863915
24	24	240	6.03	192	96	1	0.954516
24	24	240	6.03	168	0	0.45	0.655818
24	24	240	6.03	168	24	0.65	0.713705
24	24	240	6.03	168	48	0.8	0.789512
24	24	240	6.03	168	72	0.9	0.873808
24	24	240	6.03	168	96	1	0.962792
24	24	240	6.03	144	0	0.4	0.681042
24	24	240	6.03	144	24	0.6	0.730752
24	24	240	6.03	144	48	0.825	0.802328
24	24	240	6.03	144	72	1	0.884055
24	24	240	6.03	144	96	1	0.971319
24	24	240	6.03	120	0	0.35	0.708283
24	24	240	6.03	120	24	0.6	0.748774
24	24	240	6.03	120	48	0.825	0.815713
24	24	240	6.03	120	72	1	0.894674
24	24	240	6.03	120	96	1	0.980109
24	24	240	6.03	96	0	0.3	0.737795
24	24	240	6.03	96	24	0.6	0.767855
24	24	240	6.03	96	48	0.9	0.829706
24	24	240	6.03	96	72	1	0.905687
24	24	240	6.03	96	96	1	0.989173
24	24	240	6.03	72	0	0.4	0.769873
24	24	240	6.03	72	24	0.6	0.788093

24	24	240	6.03	72	48	0.8	0.844351
24	24	240	6.03	72	72	0.85	0.917115
24	24	240	6.03	72	96	1	0.998525
24	24	240	6.03	48	0	0.55	0.804867
24	24	240	6.03	48	24	0.65	0.809596
24	24	240	6.03	48	48	0.775	0.859692
24	24	240	6.03	48	72	0.85	0.928982
24	24	240	6.03	48	96	1	1.008179
24	24	240	6.03	24	0	0.6	0.843194
24	24	240	6.03	24	24	0.7	0.832487
24	24	240	6.03	24	48	0.8	0.875783
24	24	240	6.03	24	72	0.85	0.941315
24	24	240	6.03	24	96	1	1.018149
24	24	240	6.03	0	0	1	0.885354
24	24	240	6.03	0	24	0.8	0.856903
24	24	240	6.03	0	48	0.85	0.892677
24	24	240	6.03	0	72	0.875	0.954142
24	24	240	6.03	0	96	1	1.028451
24	24	240	6.03	-24	0	0.8	0.931952
24	24	240	6.03	-24	24	0.825	0.883003
24	24	240	6.03	-24	48	0.875	0.910438
24	24	240	6.03	-24	72	1	0.967491
24	24	240	6.03	-24	96	1	1.039103
24	24	240	6.03	-48	0	0.85	0.983727
24	24	240	6.03	-48	24	0.875	0.910967
24	24	240	6.03	-48	48	1	0.929134
24	24	240	6.03	-48	72	1	0.981398
24	24	240	6.03	-48	96	1	1.050122
24	24	240	6.03	-72	0	1	1.041593
24	24	240	6.03	-72	24	1	0.941003
24	24	240	6.03	-72	48	1	0.94884
24	24	240	6.03	-72	72	1	0.995895
24	24	240	6.03	-72	96	1	1.061528
48	24	240	6.03	480	0	0.3	0.190236
48	24	240	6.03	480	48	0.4	0.342677
48	24	240	6.03	480	96	0.55	0.514142
48	24	240	6.03	480	144	0.8	0.695118
48	24	240	6.03	480	192	1	0.88153
48	24	240	6.03	432	0	0.2	0.231279
48	24	240	6.03	432	48	0.3	0.371976
48	24	240	6.03	432	96	0.5	0.536879
48	24	240	6.03	432	144	0.75	0.713679
48	24	240	6.03	432	192	0.95	0.897204
48	24	240	6.03	384	0	0.1	0.275253

48	24	240	6.03	384	48	0.25	0.402818
48	24	240	6.03	384	96	0.45	0.560564
48	24	240	6.03	384	144	0.675	0.732881
48	24	240	6.03	384	192	0.9	0.913339
48	24	240	6.03	336	0	0.1	0.322485
48	24	240	6.03	336	48	0.225	0.435327
48	24	240	6.03	336	96	0.4	0.585257
48	24	240	6.03	336	144	0.675	0.752756
48	24	240	6.03	336	192	0.9	0.929956
48	24	240	6.03	288	0	0.125	0.373349
48	24	240	6.03	288	48	0.25	0.469641
48	24	240	6.03	288	96	0.4	0.611024
48	24	240	6.03	288	144	0.7	0.773341
48	24	240	6.03	288	192	1	0.947077
48	24	240	6.03	240	0	0.2	0.428283
48	24	240	6.03	240	48	0.3	0.505917
48	24	240	6.03	240	96	0.5	0.637935
48	24	240	6.03	240	144	0.75	0.794674
48	24	240	6.03	240	192	1	0.964724
48	24	240	6.03	192	0	0.2	0.487795
48	24	240	6.03	192	48	0.4	0.544326
48	24	240	6.03	192	96	0.625	0.66607
48	24	240	6.03	192	144	0.8	0.816798
48	24	240	6.03	192	192	1	0.982923
48	24	240	6.03	144	0	0.4	0.552482
48	24	240	6.03	144	48	0.4	0.585063
48	24	240	6.03	144	96	0.7	0.695514
48	24	240	6.03	144	144	0.825	0.839756
48	24	240	6.03	144	192	1	1.0017
48	24	240	6.03	96	0	0.5	0.623049
48	24	240	6.03	96	48	0.625	0.628346
48	24	240	6.03	96	96	0.75	0.726359
48	24	240	6.03	96	144	0.85	0.863598
48	24	240	6.03	96	192	1	1.021082
48	24	240	6.03	48	0	0.5	0.700337
48	24	240	6.03	48	48	0.7	0.674422
48	24	240	6.03	48	96	0.8	0.758709
48	24	240	6.03	48	144	0.9	0.888374
48	24	240	6.03	48	192	1	1.0411
48	24	240	6.03	0	0	1	0.785354
48	24	240	6.03	0	48	0.8	0.723569
48	24	240	6.03	0	96	0.9	0.792677
48	24	240	6.03	0	144	0.95	0.914142
48	24	240	6.03	0	192	1	1.061785

48	24	240	6.03	-48	0	0.85	0.87932
48	24	240	6.03	-48	48	0.9	0.776106
48	24	240	6.03	-48	96	0.95	0.828387
48	24	240	6.03	-48	144	1	0.940961
48	24	240	6.03	-48	192	1	1.083171
48	24	240	6.03	-96	0	0.925	0.983727
48	24	240	6.03	-96	48	0.975	0.832396
48	24	240	6.03	-96	96	1	0.865976
48	24	240	6.03	-96	144	1	0.968898
48	24	240	6.03	-96	192	1	1.105295
48	24	240	6.03	-144	0	1	1.100417
48	24	240	6.03	-144	48	1	0.892855
48	24	240	6.03	-144	96	1	0.905597
48	24	240	6.03	-144	144	1	0.998023
48	24	240	6.03	-144	192	1	1.128194
24	24	240	7.3	240	0	0.575	0.588472
24	24	240	7.3	240	24	0.675	0.666354
24	24	240	7.3	240	48	0.775	0.753083
24	24	240	7.3	240	72	0.85	0.844236
24	24	240	7.3	240	96	1	0.937917
24	24	240	7.3	216	0	0.55	0.608764
24	24	240	7.3	216	24	0.675	0.680876
24	24	240	7.3	216	48	0.775	0.764371
24	24	240	7.3	216	72	0.85	0.85346
24	24	240	7.3	216	96	1	0.945713
24	24	240	7.3	192	0	0.5	0.630506
24	24	240	7.3	192	24	0.65	0.696162
24	24	240	7.3	192	48	0.775	0.776128
24	24	240	7.3	192	72	0.875	0.863003
24	24	240	7.3	192	96	1	0.953738
24	24	240	7.3	168	0	0.45	0.653858
24	24	240	7.3	168	24	0.65	0.712275
24	24	240	7.3	168	48	0.825	0.788387
24	24	240	7.3	168	72	0.875	0.87288
24	24	240	7.3	168	96	1	0.962002
24	24	240	7.3	144	0	0.4	0.679006
24	24	240	7.3	144	24	0.525	0.729282
24	24	240	7.3	144	48	0.825	0.801178
24	24	240	7.3	144	72	1	0.88311
24	24	240	7.3	144	96	1	0.970518
24	24	240	7.3	120	0	0.35	0.706167
24	24	240	7.3	120	24	0.6	0.747262
24	24	240	7.3	120	48	0.825	0.814537
24	24	240	7.3	120	72	1	0.893712

24	24	240	7.3	120	96	1	0.979295
24	24	240	7.3	96	0	0.25	0.73559
24	24	240	7.3	96	24	0.575	0.766299
24	24	240	7.3	96	48	0.825	0.828504
24	24	240	7.3	96	72	0.9	0.904707
24	24	240	7.3	96	96	1	0.988346
24	24	240	7.3	72	0	0.5	0.767572
24	24	240	7.3	72	24	0.6	0.78649
24	24	240	7.3	72	48	0.8	0.84312
24	24	240	7.3	72	72	0.85	0.916116
24	24	240	7.3	72	96	0.9	0.997685
24	24	240	7.3	48	0	0.6	0.802462
24	24	240	7.3	48	24	0.625	0.807943
24	24	240	7.3	48	48	0.775	0.858433
24	24	240	7.3	48	72	0.85	0.927965
24	24	240	7.3	48	96	0.9	1.007325
24	24	240	7.3	24	0	0.6	0.840675
24	24	240	7.3	24	24	0.7	0.83078
24	24	240	7.3	24	48	0.775	0.874492
24	24	240	7.3	24	72	0.85	0.940278
24	24	240	7.3	24	96	1	1.017281
24	24	240	7.3	0	0	1	0.882708
24	24	240	7.3	0	24	0.75	0.855139
24	24	240	7.3	0	48	0.825	0.891354
24	24	240	7.3	0	72	0.875	0.953083
24	24	240	7.3	0	96	1	1.027569
24	24	240	7.3	-24	0	0.75	0.929167
24	24	240	7.3	-24	24	0.825	0.881178
24	24	240	7.3	-24	48	0.85	0.909081
24	24	240	7.3	-24	72	1	0.966412
24	24	240	7.3	-24	96	1	1.038206
24	24	240	7.3	-48	0	0.85	0.980787
24	24	240	7.3	-48	24	0.875	0.909077
24	24	240	7.3	-48	48	1	0.927741
24	24	240	7.3	-48	72	1	0.980295
24	24	240	7.3	-48	96	1	1.04921
24	24	240	7.3	-72	0	1	1.03848
24	24	240	7.3	-72	24	1	0.939043
24	24	240	7.3	-72	48	1	0.94741
24	24	240	7.3	-72	72	1	0.99477
24	24	240	7.3	-72	96	1	1.060599
48	24	240	7.3	480	0	0.25	0.188472
48	24	240	7.3	480	48	0.35	0.341354
48	24	240	7.3	480	96	0.525	0.513083

48	24	240	7.3	480	144	0.75	0.694236
48	24	240	7.3	480	192	1	0.880774
48	24	240	7.3	432	0	0.15	0.229454
48	24	240	7.3	432	48	0.3	0.37062
48	24	240	7.3	432	96	0.5	0.535799
48	24	240	7.3	432	144	0.725	0.712782
48	24	240	7.3	432	192	0.85	0.896437
48	24	240	7.3	384	0	0.1	0.273363
48	24	240	7.3	384	48	0.25	0.401425
48	24	240	7.3	384	96	0.425	0.559462
48	24	240	7.3	384	144	0.675	0.731968
48	24	240	7.3	384	192	0.875	0.912561
48	24	240	7.3	336	0	0.1	0.320525
48	24	240	7.3	336	48	0.25	0.433896
48	24	240	7.3	336	96	0.425	0.584131
48	24	240	7.3	336	144	0.675	0.751827
48	24	240	7.3	336	192	0.875	0.929167
48	24	240	7.3	288	0	0.1	0.371314
48	24	240	7.3	288	48	0.25	0.468171
48	24	240	7.3	288	96	0.4	0.609873
48	24	240	7.3	288	144	0.7	0.772396
48	24	240	7.3	288	192	1	0.946275
48	24	240	7.3	240	0	0.15	0.426167
48	24	240	7.3	240	48	0.375	0.504405
48	24	240	7.3	240	96	0.525	0.636759
48	24	240	7.3	240	144	0.75	0.793712
48	24	240	7.3	240	192	1	0.96391
48	24	240	7.3	192	0	0.2	0.48559
48	24	240	7.3	192	48	0.4	0.54277
48	24	240	7.3	192	96	0.625	0.664867
48	24	240	7.3	192	144	0.8	0.815818
48	24	240	7.3	192	192	1	0.982096
48	24	240	7.3	144	0	0.35	0.550181
48	24	240	7.3	144	48	0.5	0.58346
48	24	240	7.3	144	96	0.675	0.694283
48	24	240	7.3	144	144	0.825	0.838758
48	24	240	7.3	144	192	1	1.00086
48	24	240	7.3	96	0	0.5	0.620644
48	24	240	7.3	96	48	0.625	0.626693
48	24	240	7.3	96	96	0.75	0.725099
48	24	240	7.3	96	144	0.875	0.86258
48	24	240	7.3	96	192	1	1.020228
48	24	240	7.3	48	0	0.625	0.697817
48	24	240	7.3	48	48	0.725	0.672715

48	24	240	7.3	48	96	0.825	0.757419
48	24	240	7.3	48	144	0.925	0.887337
48	24	240	7.3	48	192	1	1.040232
48	24	240	7.3	0	0	1	0.782708
48	24	240	7.3	0	48	0.8	0.721806
48	24	240	7.3	0	96	0.875	0.791354
48	24	240	7.3	0	144	0.975	0.913083
48	24	240	7.3	0	192	1	1.060903
48	24	240	7.3	-48	0	0.85	0.876535
48	24	240	7.3	-48	48	0.9	0.774282
48	24	240	7.3	-48	96	0.95	0.82703
48	24	240	7.3	-48	144	1	0.939881
48	24	240	7.3	-48	192	1	1.082274
48	24	240	7.3	-96	0	0.95	0.980787
48	24	240	7.3	-96	48	0.975	0.830506
48	24	240	7.3	-96	96	1	0.864583
48	24	240	7.3	-96	144	1	0.967795
48	24	240	7.3	-96	192	1	1.104382
48	24	240	7.3	-144	0	1	1.097304
48	24	240	7.3	-144	48	1	0.890895
48	24	240	7.3	-144	96	1	0.904167
48	24	240	7.3	-144	144	1	0.996897
48	24	240	7.3	-144	192	1	1.127266

Table-4.4 Table showing the Input & Output Parameters used and results obtained using GP for Max ALDSP.

B	D	H	R_v	X	Y	MAX ALDSP EXPERIMENTAL VALUES	GP OBTAINED VALUES
24	24	240	6.03	240	0	1	1.0159456
24	24	240	6.03	240	24	1.25	1.0620484
24	24	240	6.03	240	48	1.5	1.0864622
24	24	240	6.03	240	72	1.25	1.1015777
24	24	240	6.03	240	96	1	1.1118572
24	24	240	6.03	216	0	1	1.0060671
24	24	240	6.03	216	24	1.25	1.0552083
24	24	240	6.03	216	48	1.5	1.0812311
24	24	240	6.03	216	72	1.25	1.0973427
24	24	240	6.03	216	96	1	1.1082997
24	24	240	6.03	192	0	1	0.9964484
24	24	240	6.03	192	24	1.25	1.0485481
24	24	240	6.03	192	48	1.5	1.0761375
24	24	240	6.03	192	72	1.5	1.0932191
24	24	240	6.03	192	96	1.25	1.1048357
24	24	240	6.03	168	0	1	0.9871353
24	24	240	6.03	168	24	1.25	1.0420994
24	24	240	6.03	168	48	1.5	1.0712057
24	24	240	6.03	168	72	1.25	1.0892265
24	24	240	6.03	168	96	1.25	1.1014818
24	24	240	6.03	144	0	1	0.9781851
24	24	240	6.03	144	24	1.25	1.0359021
24	24	240	6.03	144	48	1.5	1.0664661
24	24	240	6.03	144	72	1.25	1.0853895
24	24	240	6.03	144	96	1.25	1.0982586
24	24	240	6.03	120	0	1	0.9696704
24	24	240	6.03	120	24	1	1.0300063
24	24	240	6.03	120	48	1.25	1.0619572
24	24	240	6.03	120	72	1.25	1.0817392
24	24	240	6.03	120	96	1	1.0951922
24	24	240	6.03	96	0	1	0.9616845
24	24	240	6.03	96	24	1	1.0244766
24	24	240	6.03	96	48	1.25	1.0577282
24	24	240	6.03	96	72	1.25	1.0783156
24	24	240	6.03	96	96	1	1.0923163
24	24	240	6.03	72	0	1	0.9543494
24	24	240	6.03	72	24	1	1.0193977
24	24	240	6.03	72	48	1	1.053844
24	24	240	6.03	72	72	1	1.075171

24	24	240	6.03	72	96	1	1.0896747
24	24	240	6.03	48	0	1	0.9478279
24	24	240	6.03	48	24	1	1.014882
24	24	240	6.03	48	48	1	1.0503905
24	24	240	6.03	48	72	1	1.0723752
24	24	240	6.03	48	96	1	1.0873261
24	24	240	6.03	24	0	1	0.9423418
24	24	240	6.03	24	24	1	1.0110833
24	24	240	6.03	24	48	1	1.0474853
24	24	240	6.03	24	72	1	1.0700232
24	24	240	6.03	24	96	1	1.0853504
24	24	240	6.03	0	0	1	0.9382018
24	24	240	6.03	0	24	1	1.0082166
24	24	240	6.03	0	48	1	1.045293
24	24	240	6.03	0	72	1	1.0682484
24	24	240	6.03	0	96	1	1.0838595
24	24	240	6.03	-24	0	1	0.9358565
24	24	240	6.03	-24	24	1	1.0065927
24	24	240	6.03	-24	48	1	1.044051
24	24	240	6.03	-24	72	1	1.0672429
24	24	240	6.03	-24	96	1	1.0830149
24	24	240	6.03	-48	0	1	0.935979
24	24	240	6.03	-48	24	1	1.0066775
24	24	240	6.03	-48	48	1	1.0441159
24	24	240	6.03	-48	72	1	1.0672954
24	24	240	6.03	-48	96	1	1.083059
24	24	240	6.03	-72	0	1	0.9396268
24	24	240	6.03	-72	24	1	1.0092033
24	24	240	6.03	-72	48	1	1.0460476
24	24	240	6.03	-72	72	1	1.0688593
24	24	240	6.03	-72	96	1	1.0843727
48	24	240	6.03	480	0	0.75	0.8771149
48	24	240	6.03	480	48	1	0.9694877
48	24	240	6.03	480	96	1.25	1.0170804
48	24	240	6.03	480	144	1.25	1.0461026
48	24	240	6.03	480	192	1.5	1.0656492
48	24	240	6.03	432	0	0.75	0.8686571
48	24	240	6.03	432	48	1	0.9637358
48	24	240	6.03	432	96	1	1.0127227
48	24	240	6.03	432	144	1.25	1.0425951
48	24	240	6.03	432	192	1.25	1.0627143
48	24	240	6.03	384	0	0.75	0.8608885
48	24	240	6.03	384	48	0.75	0.9584527
48	24	240	6.03	384	96	0.75	1.0087201

48	24	240	6.03	384	144	1	1.0393735
48	24	240	6.03	384	192	1.25	1.0600185
48	24	240	6.03	336	0	0.75	0.8539816
48	24	240	6.03	336	48	0.75	0.9537555
48	24	240	6.03	336	96	0.75	1.0051615
48	24	240	6.03	336	144	0.75	1.0365091
48	24	240	6.03	336	192	1.25	1.0576218
48	24	240	6.03	288	0	1	0.8481712
48	24	240	6.03	288	48	1	0.9498041
48	24	240	6.03	288	96	0.75	1.0021679
48	24	240	6.03	288	144	1	1.0340995
48	24	240	6.03	288	192	1.25	1.0556056
48	24	240	6.03	240	0	0.75	0.8437865
48	24	240	6.03	240	48	1	0.9468222
48	24	240	6.03	240	96	0.75	0.9999088
48	24	240	6.03	240	144	0.75	1.0322812
48	24	240	6.03	240	192	1	1.0540841
48	24	240	6.03	192	0	0.75	0.8413026
48	24	240	6.03	192	48	0.75	0.945133
48	24	240	6.03	192	96	1	0.998629
48	24	240	6.03	192	144	1	1.0312511
48	24	240	6.03	192	192	1	1.0532221
48	24	240	6.03	144	0	0.75	0.8414323
48	24	240	6.03	144	48	0.75	0.9452212
48	24	240	6.03	144	96	1	0.9986958
48	24	240	6.03	144	144	1	1.0313049
48	24	240	6.03	144	192	1	1.0532671
48	24	240	6.03	96	0	0.75	0.8452958
48	24	240	6.03	96	48	1	0.9478486
48	24	240	6.03	96	96	1	1.0006864
48	24	240	6.03	96	144	1	1.0329071
48	24	240	6.03	96	192	1.25	1.0546078
48	24	240	6.03	48	0	1	0.8547598
48	24	240	6.03	48	48	1	0.9542848
48	24	240	6.03	48	96	1	1.0055625
48	24	240	6.03	48	144	1.25	1.0368318
48	24	240	6.03	48	192	1.25	1.0578918
48	24	240	6.03	0	0	1	0.8731848
48	24	240	6.03	0	48	1	0.9668149
48	24	240	6.03	0	96	1	1.0150555
48	24	240	6.03	0	144	1.25	1.0444728
48	24	240	6.03	0	192	1.25	1.0642854
48	24	240	6.03	-48	0	1	0.9072914
48	24	240	6.03	-48	48	1	0.9900096

48	24	240	6.03	-48	96	1.25	1.0326281
48	24	240	6.03	-48	144	1.25	1.058617
48	24	240	6.03	-48	192	1.25	1.0761206
48	24	240	6.03	-96	0	1	0.9727614
48	24	240	6.03	-96	48	1.1	1.0345334
48	24	240	6.03	-96	96	1.25	1.0663599
48	24	240	6.03	-96	144	1.25	1.0857678
48	24	240	6.03	-96	192	1.25	1.098839
48	24	240	6.03	-144	0	1	1.1166397
48	24	240	6.03	-144	48	1.25	1.1323798
48	24	240	6.03	-144	96	1.25	1.1404895
48	24	240	6.03	-144	144	1.25	1.1454349
48	24	240	6.03	-144	192	1.5	1.1487656
24	24	240	7.3	240	0	0.75	0.8980351
24	24	240	7.3	240	24	1	0.9703533
24	24	240	7.3	240	48	1.25	1.0090676
24	24	240	7.3	240	72	1.25	1.0331843
24	24	240	7.3	240	96	1.25	1.0496499
24	24	240	7.3	216	0	0.75	0.8921753
24	24	240	7.3	216	24	1	0.9662669
24	24	240	7.3	216	48	1.25	1.0059306
24	24	240	7.3	216	72	1.25	1.0306387
24	24	240	7.3	216	96	1	1.0475081
24	24	240	7.3	192	0	0.75	0.8865692
24	24	240	7.3	192	24	1	0.9623575
24	24	240	7.3	192	48	1.25	1.0029295
24	24	240	7.3	192	72	1.25	1.0282034
24	24	240	7.3	192	96	1	1.0454591
24	24	240	7.3	168	0	0.75	0.8812618
24	24	240	7.3	168	24	1	0.9586563
24	24	240	7.3	168	48	1.25	1.0000883
24	24	240	7.3	168	72	1.25	1.0258978
24	24	240	7.3	168	96	1	1.0435192
24	24	240	7.3	144	0	0.75	0.8763089
24	24	240	7.3	144	24	1	0.9552024
24	24	240	7.3	144	48	1.25	0.9974368
24	24	240	7.3	144	72	1.25	1.0237462
24	24	240	7.3	144	96	1	1.041709
24	24	240	7.3	120	0	0.75	0.8717814
24	24	240	7.3	120	24	1	0.9520452
24	24	240	7.3	120	48	1	0.9950131
24	24	240	7.3	120	72	1	1.0217795
24	24	240	7.3	120	96	1	1.0400542
24	24	240	7.3	96	0	0.75	0.8677707

24	24	240	7.3	96	24	1	0.9492483
24	24	240	7.3	96	48	1	0.992866
24	24	240	7.3	96	72	1	1.0200372
24	24	240	7.3	96	96	1	1.0385883
24	24	240	7.3	72	0	0.75	0.8643958
24	24	240	7.3	72	24	0.75	0.9468948
24	24	240	7.3	72	48	1	0.9910594
24	24	240	7.3	72	72	1	1.0185711
24	24	240	7.3	72	96	1	1.0373548
24	24	240	7.3	48	0	0.75	0.8618158
24	24	240	7.3	48	24	0.75	0.9450957
24	24	240	7.3	48	48	1	0.9896782
24	24	240	7.3	48	72	1	1.0174504
24	24	240	7.3	48	96	1	1.0364118
24	24	240	7.3	24	0	1	0.8602475
24	24	240	7.3	24	24	0.75	0.944002
24	24	240	7.3	24	48	1	0.9888386
24	24	240	7.3	24	72	1	1.0167691
24	24	240	7.3	24	96	1	1.0358385
24	24	240	7.3	0	0	1	0.8599943
24	24	240	7.3	0	24	1	0.9438254
24	24	240	7.3	0	48	1	0.9887031
24	24	240	7.3	0	72	1	1.0166591
24	24	240	7.3	0	96	1	1.035746
24	24	240	7.3	-24	0	1	0.8614946
24	24	240	7.3	-24	24	1	0.9448717
24	24	240	7.3	-24	48	1	0.9895062
24	24	240	7.3	-24	72	1	1.0173108
24	24	240	7.3	-24	96	1	1.0362944
24	24	240	7.3	-48	0	1	0.865406
24	24	240	7.3	-48	24	1	0.9475993
24	24	240	7.3	-48	48	1	0.9916001
24	24	240	7.3	-48	72	1	1.0190099
24	24	240	7.3	-48	96	1	1.037724
24	24	240	7.3	-72	0	1	0.8727618
24	24	240	7.3	-72	24	1	0.9527289
24	24	240	7.3	-72	48	1	0.995538
24	24	240	7.3	-72	72	1	1.0222054
24	24	240	7.3	-72	96	1	1.0404125
48	24	240	7.3	480	0	0.75	0.7954018
48	24	240	7.3	480	48	1	0.9037696
48	24	240	7.3	480	96	1.25	0.9599382
48	24	240	7.3	480	144	1.25	0.9943026
48	24	240	7.3	480	192	1	1.0174953

48	24	240	7.3	432	0	0.75	0.7911076
48	24	240	7.3	432	48	1	0.9008378
48	24	240	7.3	432	96	1.25	0.9577125
48	24	240	7.3	432	144	1	0.9925089
48	24	240	7.3	432	192	1.25	1.0159932
48	24	240	7.3	384	0	0.75	0.7874942
48	24	240	7.3	384	48	1	0.8983708
48	24	240	7.3	384	96	1.25	0.9558396
48	24	240	7.3	384	144	1	0.9909995
48	24	240	7.3	384	192	1.25	1.0147292
48	24	240	7.3	336	0	0.75	0.7847319
48	24	240	7.3	336	48	1	0.8964848
48	24	240	7.3	336	96	1	0.9544079
48	24	240	7.3	336	144	1.25	0.9898457
48	24	240	7.3	336	192	1.25	1.0137629
48	24	240	7.3	288	0	0.75	0.7830527
48	24	240	7.3	288	48	0.75	0.8953383
48	24	240	7.3	288	96	1	0.9535375
48	24	240	7.3	288	144	1.25	0.9891443
48	24	240	7.3	288	192	1.5	1.0131755
48	24	240	7.3	240	0	0.75	0.7827816
48	24	240	7.3	240	48	0.75	0.8951532
48	24	240	7.3	240	96	1	0.953397
48	24	240	7.3	240	144	1	0.989031
48	24	240	7.3	240	192	1.25	1.0130806
48	24	240	7.3	192	0	0.5	0.784388
48	24	240	7.3	192	48	0.75	0.89625
48	24	240	7.3	192	96	1	0.9542296
48	24	240	7.3	192	144	1.25	0.989702
48	24	240	7.3	192	192	1	1.0136426
48	24	240	7.3	144	0	0.5	0.7885758
48	24	240	7.3	144	48	0.75	0.8991092
48	24	240	7.3	144	96	1	0.9564002
48	24	240	7.3	144	144	1	0.9914513
48	24	240	7.3	144	192	1	1.0151075
48	24	240	7.3	96	0	0.75	0.7964514
48	24	240	7.3	96	48	0.75	0.9044863
48	24	240	7.3	96	96	1	0.9604823
48	24	240	7.3	96	144	1	0.994741
48	24	240	7.3	96	192	1	1.0178625
48	24	240	7.3	48	0	0.75	0.8098588
48	24	240	7.3	48	48	0.75	0.9136402
48	24	240	7.3	48	96	0.75	0.9674315
48	24	240	7.3	48	144	1	1.0003415

48	24	240	7.3	48	192	1	1.0225526
48	24	240	7.3	0	0	1	0.832117
48	24	240	7.3	0	48	1	0.9288369
48	24	240	7.3	0	96	1	0.9789682
48	24	240	7.3	0	144	1	1.0096389
48	24	240	7.3	0	192	1.25	1.0303388
48	24	240	7.3	-48	0	1	0.869864
48	24	240	7.3	-48	48	1	0.9546087
48	24	240	7.3	-48	96	1.25	0.9985331
48	24	240	7.3	-48	144	1.25	1.0254063
48	24	240	7.3	-48	192	1.25	1.0435433
48	24	240	7.3	-96	0	1	0.9385888
48	24	240	7.3	-96	48	1	1.0015305
48	24	240	7.3	-96	96	1.25	1.0341541
48	24	240	7.3	-96	144	1.25	1.0541134
48	24	240	7.3	-96	192	1.25	1.0675841
48	24	240	7.3	-144	0	1	1.0847579
48	24	240	7.3	-144	48	1.25	1.1013274
48	24	240	7.3	-144	96	1.25	1.1099156
48	24	240	7.3	-144	144	1.25	1.1151699
48	24	240	7.3	-144	192	1.25	1.1187161

Table-4.5 Table showing the Input & Output Parameters used and results obtained using GP for Peak ACDSP.

B	D	H	R_v	X	Y	PEAK ALDSP EXPERIMENTAL VALUES	GP OBTAINED VALUES
24	24	240	4.86	240	0	3.75	3.7298178
24	24	240	4.86	240	24	4.5	4.0402659
24	24	240	4.86	240	48	5	4.6926471
24	24	240	4.86	240	72	3.5	3.4814446
24	24	240	4.86	240	96	2.5	2.3392774
24	24	240	4.86	216	0	4	3.5406388
24	24	240	4.86	216	24	4.5	4.9101592
24	24	240	4.86	216	48	4.5	4.5934998
24	24	240	4.86	216	72	3.5	3.4013549
24	24	240	4.86	216	96	2.5	2.2721002
24	24	240	4.86	192	0	3.75	3.3514598
24	24	240	4.86	192	24	4.5	4.7800525
24	24	240	4.86	192	48	4.5	4.4943525
24	24	240	4.86	192	72	3.25	3.3212652
24	24	240	4.86	192	96	2.5	2.204923
24	24	240	4.86	168	0	3.25	3.1622809
24	24	240	4.86	168	24	3.75	3.6499458
24	24	240	4.86	168	48	3.75	3.3952051
24	24	240	4.86	168	72	3.25	3.2411754
24	24	240	4.86	168	96	2.5	2.1377458
24	24	240	4.86	144	0	3	2.9731019
24	24	240	4.86	144	24	3.5	2.5198391
24	24	240	4.86	144	48	3.75	2.2960578
24	24	240	4.86	144	72	3.25	2.1610857
24	24	240	4.86	144	96	2.25	2.0705685
24	24	240	4.86	120	0	3	2.7839229
24	24	240	4.86	120	24	3.5	2.3897324
24	24	240	4.86	120	48	3.75	3.1969105
24	24	240	4.86	120	72	3	2.080996
24	24	240	4.86	120	96	2	2.0033913
24	24	240	4.86	96	0	3	2.594744
24	24	240	4.86	96	24	3.5	3.2596257
24	24	240	4.86	96	48	3.75	3.0977631
24	24	240	4.86	96	72	2.75	2.0009063
24	24	240	4.86	96	96	1.5	1.9362141
24	24	240	4.86	72	0	2.75	2.405565
24	24	240	4.86	72	24	3.25	2.129519
24	24	240	4.86	72	48	3.25	2.9986158

24	24	240	4.86	72	72	2.5	1.9208166
24	24	240	4.86	72	96	1.5	1.8690369
24	24	240	4.86	48	0	2.75	2.2163861
24	24	240	4.86	48	24	2.75	1.9994124
24	24	240	4.86	48	48	2.5	1.8994685
24	24	240	4.86	48	72	2.25	1.8407269
24	24	240	4.86	48	96	1.5	1.8018597
24	24	240	4.86	24	0	2.25	2.0272071
24	24	240	4.86	24	24	2.25	1.8693057
24	24	240	4.86	24	48	2	1.8003211
24	24	240	4.86	24	72	1.75	1.7606372
24	24	240	4.86	24	96	1.5	1.7346825
24	24	240	4.86	0	0	1	0.8380281
24	24	240	4.86	0	24	1.75	1.739199
24	24	240	4.86	0	48	1.75	1.7011738
24	24	240	4.86	0	72	1.75	1.6805475
24	24	240	4.86	0	96	1	1.2675053
24	24	240	4.86	-24	0	1	1.1588492
24	24	240	4.86	-24	24	1	1.2390923
24	24	240	4.86	-24	48	1	1.1620265
24	24	240	4.86	-24	72	1	1.1600458
24	24	240	4.86	-24	96	1	1.1600328
24	24	240	4.86	-48	0	1	1.2596702
24	24	240	4.86	-48	24	1	1.1789856
24	24	240	4.86	-48	48	1	1.2028791
24	24	240	4.86	-48	72	1	1.1203681
24	24	240	4.86	-48	96	1	1.2331508
24	24	240	4.86	-72	0	1	1.2704912
24	24	240	4.86	-72	24	1	1.2888789
24	24	240	4.86	-72	48	1	1.2137318
24	24	240	4.86	-72	72	1	1.4402784
24	24	240	4.86	-72	96	1	1.2359736
48	24	240	4.86	480	0	1	1.2215855
48	24	240	4.86	480	48	1.5	1.6728114
48	24	240	4.86	480	96	1.5	1.6813578
48	24	240	4.86	480	144	1.5	1.6912308
48	24	240	4.86	480	192	1.5	1.7036466
48	24	240	4.86	432	0	1	1.2398162
48	24	240	4.86	432	48	1	1.2149043
48	24	240	4.86	432	96	1	1.2281808
48	24	240	4.86	432	144	1	1.1439818
48	24	240	4.86	432	192	1	1.264044
48	24	240	4.86	384	0	1.5	1.7380469
48	24	240	4.86	384	48	1	1.1569971

48	24	240	4.86	384	96	1	1.1750039
48	24	240	4.86	384	144	1	1.1967328
48	24	240	4.86	384	192	1	1.1244414
48	24	240	4.86	336	0	1.75	1.7762775
48	24	240	4.86	336	48	1.5	1.79909
48	24	240	4.86	336	96	1.25	1.321827
48	24	240	4.86	336	144	1.25	1.3494837
48	24	240	4.86	336	192	1.25	1.3848389
48	24	240	4.86	288	0	2.25	1.8145082
48	24	240	4.86	288	48	1.375	1.8411828
48	24	240	4.86	288	96	1.125	1.16865
48	24	240	4.86	288	144	1.125	1.1022347
48	24	240	4.86	288	192	1.125	1.1523627
48	24	240	4.86	240	0	2.5	1.8527389
48	24	240	4.86	240	48	1.375	1.5832757
48	24	240	4.86	240	96	1.125	1.1915473
48	24	240	4.86	240	144	1	1.0549857
48	24	240	4.86	240	192	1	1.0056337
48	24	240	4.86	192	0	2.5	1.8909696
48	24	240	4.86	192	48	1.75	1.9253685
48	24	240	4.86	192	96	1	1.1622961
48	24	240	4.86	192	144	1	1.0077366
48	24	240	4.86	192	192	1	1.0660311
48	24	240	4.86	144	0	2.25	1.9292003
48	24	240	4.86	144	48	1.375	1.6674614
48	24	240	4.86	144	96	1.25	1.0091192
48	24	240	4.86	144	144	1.125	1.0604876
48	24	240	4.86	144	192	1.125	1.1264285
48	24	240	4.86	96	0	1.875	1.967431
48	24	240	4.86	96	48	1.625	2.0095543
48	24	240	4.86	96	96	1	1.0559422
48	24	240	4.86	96	144	1.125	1.1132385
48	24	240	4.86	96	192	1.125	1.1868259
48	24	240	4.86	48	0	1.75	2.0056616
48	24	240	4.86	48	48	1.5	2.0164712
48	24	240	4.86	48	96	1	1.1027653
48	24	240	4.86	48	144	1	1.1659895
48	24	240	4.86	48	192	1.125	1.2472233
48	24	240	4.86	0	0	1	1.0438923
48	24	240	4.86	0	48	1	1.09374
48	24	240	4.86	0	96	1	1.1495883
48	24	240	4.86	0	144	1	1.2187405
48	24	240	4.86	0	192	1	1.3076208
48	24	240	4.86	-48	0	1	1.082123

48	24	240	4.86	-48	48	1	1.1358328
48	24	240	4.86	-48	96	1	1.1964114
48	24	240	4.86	-48	144	1	1.2714914
48	24	240	4.86	-48	192	1	1.3680182
48	24	240	4.86	-96	0	1	1.1203537
48	24	240	4.86	-96	48	1	1.1779257
48	24	240	4.86	-96	96	1	1.2432345
48	24	240	4.86	-96	144	1	1.3242424
48	24	240	4.86	-96	192	1	1.2284156
48	24	240	4.86	-144	0	1	1.1585844
48	24	240	4.86	-144	48	1	1.2200185
48	24	240	4.86	-144	96	1	1.2900575
48	24	240	4.86	-144	144	1	1.1769934
48	24	240	4.86	-144	192	1	1.188813
24	24	240	5.88	240	0	5.5	5.1067681
24	24	240	5.88	240	24	4.5	4.4410546
24	24	240	5.88	240	48	3.5	3.1026196
24	24	240	5.88	240	72	3.5	2.8959935
24	24	240	5.88	240	96	1	1.2564674
24	24	240	5.88	216	0	6.5	6.9211705
24	24	240	5.88	216	24	5.5	5.3126519
24	24	240	5.88	216	48	4.5	4.0044649
24	24	240	5.88	216	72	3.5	2.8165528
24	24	240	5.88	216	96	1	1.1897474
24	24	240	5.88	192	0	7	5.7355729
24	24	240	5.88	192	24	6	5.1842493
24	24	240	5.88	192	48	4.5	4.9063103
24	24	240	5.88	192	72	3.5	2.7371121
24	24	240	5.88	192	96	1	1.2230273
24	24	240	5.88	168	0	7.5	7.5499753
24	24	240	5.88	168	24	7	5.0558466
24	24	240	5.88	168	48	5	4.8081556
24	24	240	5.88	168	72	3.5	2.6576713
24	24	240	5.88	168	96	1	1.1563073
24	24	240	5.88	144	0	10	8.3643776
24	24	240	5.88	144	24	7.5	6.9274439
24	24	240	5.88	144	48	5	4.7100009
24	24	240	5.88	144	72	3.5	2.5782306
24	24	240	5.88	144	96	1	1.2895872
24	24	240	5.88	120	0	8	5.17878
24	24	240	5.88	120	24	6	4.7990413
24	24	240	5.88	120	48	3.5	2.6118462
24	24	240	5.88	120	72	2.5	2.4987899
24	24	240	5.88	120	96	1	1.4228672

24	24	240	5.88	96	0	6	4.9931824
24	24	240	5.88	96	24	4	3.6706386
24	24	240	5.88	96	48	2	2.5136915
24	24	240	5.88	96	72	1.5	1.4193491
24	24	240	5.88	96	96	1.5	1.3561471
24	24	240	5.88	72	0	4.5	3.8075848
24	24	240	5.88	72	24	3	2.5422359
24	24	240	5.88	72	48	1.5	1.4155368
24	24	240	5.88	72	72	1.5	1.3399084
24	24	240	5.88	72	96	1	1.1894271
24	24	240	5.88	48	0	3.5	3.6219871
24	24	240	5.88	48	24	2.5	2.4138332
24	24	240	5.88	48	48	1.5	1.3173821
24	24	240	5.88	48	72	1.5	1.2604676
24	24	240	5.88	48	96	1	1.2227071
24	24	240	5.88	24	0	3	2.4363895
24	24	240	5.88	24	24	2.5	2.2854306
24	24	240	5.88	24	48	1.5	1.2192274
24	24	240	5.88	24	72	1.5	1.1810269
24	24	240	5.88	24	96	1	1.155987
24	24	240	5.88	0	0	1	1.2507919
24	24	240	5.88	0	24	1	1.1570279
24	24	240	5.88	0	48	1	1.1210727
24	24	240	5.88	0	72	1	1.1015862
24	24	240	5.88	0	96	1	1.089267
24	24	240	5.88	-24	0	1	1.0651943
24	24	240	5.88	-24	24	1	1.0286252
24	24	240	5.88	-24	48	1	1.022918
24	24	240	5.88	-24	72	1	1.0221454
24	24	240	5.88	-24	96	1	1.0225469
24	24	240	5.88	-48	0	1	1.1879597
24	24	240	5.88	-48	24	1	0.9002226
24	24	240	5.88	-48	48	1	0.9247633
24	24	240	5.88	-48	72	1	0.9427047
24	24	240	5.88	-48	96	1	0.9558269
24	24	240	5.88	-72	0	1	0.693999
24	24	240	5.88	-72	24	1	1.2718199
24	24	240	5.88	-72	48	1	1.2266086
24	24	240	5.88	-72	72	1	1.263264
24	24	240	5.88	-72	96	1	1.2891068
48	24	240	5.88	480	0	1	1.0875035
48	24	240	5.88	480	48	1	1.0988465
48	24	240	5.88	480	1	1	1.0879273
48	24	240	5.88	480	144	1	1.1175784

48	24	240	5.88	480	192	1	1.1302285
48	24	240	5.88	432	0	1	1.1258089
48	24	240	5.88	432	48	1	1.1410299
48	24	240	5.88	432	96	1	1.1544651
48	24	240	5.88	432	144	1	1.1704717
48	24	240	5.88	432	192	2	1.1908125
48	24	240	5.88	384	0	1	1.1641143
48	24	240	5.88	384	48	1	1.1832133
48	24	240	5.88	384	96	1	1.2014002
48	24	240	5.88	384	144	2	2.223365
48	24	240	5.88	384	192	2	2.2513966
48	24	240	5.88	336	0	3	2.2024196
48	24	240	5.88	336	48	2.5	2.2253968
48	24	240	5.88	336	96	2	2.2483354
48	24	240	5.88	336	144	2	2.2762582
48	24	240	5.88	336	192	2	2.3119806
48	24	240	5.88	288	0	3	2.240725
48	24	240	5.88	288	48	2.5	2.2675802
48	24	240	5.88	288	96	2	2.2952705
48	24	240	5.88	288	144	2	2.3291515
48	24	240	5.88	288	192	2	2.3725646
48	24	240	5.88	240	0	3	2.2790304
48	24	240	5.88	240	48	2.5	2.3097636
48	24	240	5.88	240	96	2	2.3422056
48	24	240	5.88	240	144	2	2.3820448
48	24	240	5.88	240	192	2	2.4331487
48	24	240	5.88	192	0	3	2.3173357
48	24	240	5.88	192	48	2.5	2.351947
48	24	240	5.88	192	96	2	2.3891408
48	24	240	5.88	192	144	2	2.434938
48	24	240	5.88	192	192	2	2.4937327
48	24	240	5.88	144	0	1	1.3556411
48	24	240	5.88	144	48	2	2.3941304
48	24	240	5.88	144	96	2	2.4360759
48	24	240	5.88	144	144	2	2.4878313
48	24	240	5.88	144	192	2	2.5543167
48	24	240	5.88	96	0	1	1.3939465
48	24	240	5.88	96	48	1	1.4363138
48	24	240	5.88	96	96	2.5	2.483011
48	24	240	5.88	96	144	2.5	2.5407245
48	24	240	5.88	96	192	3	2.6149008
48	24	240	5.88	48	0	1	1.4322518
48	24	240	5.88	48	48	1	1.4784972
48	24	240	5.88	48	96	3	2.5299462

48	24	240	5.88	48	144	3.5	2.5936178
48	24	240	5.88	48	192	3.5	2.6754848
48	24	240	5.88	0	0	1	1.2705572
48	24	240	5.88	0	48	3	2.5206807
48	24	240	5.88	0	96	3.5	2.5768813
48	24	240	5.88	0	144	4.5	3.6465111
48	24	240	5.88	0	192	5	4.7360688
48	24	240	5.88	-48	0	2	2.5088626
48	24	240	5.88	-48	48	3	2.5628641
48	24	240	5.88	-48	96	4	3.6238165
48	24	240	5.88	-48	144	5	4.6994043
48	24	240	5.88	-48	192	6	5.7966528
48	24	240	5.88	-96	0	2	2.547168
48	24	240	5.88	-96	48	3	2.6050475
48	24	240	5.88	-96	96	4.5	3.6707516
48	24	240	5.88	-96	144	6.5	4.7522976
48	24	240	5.88	-96	192	7.5	5.8572369
48	24	240	5.88	-144	0	1	1.5854733
48	24	240	5.88	-144	48	3	2.6472309
48	24	240	5.88	-144	96	5	4.7176867
48	24	240	5.88	-144	144	7	5.8051908
48	24	240	5.88	-144	192	8	6.9178209

Table-4.6 Table showing the Input & Output Parameters used and results obtained using GP for Peak ACACN.

B	D	H	R_v	X	Y	PEAK ALDSP EXPERIMENTAL VALUES	GP OBTAINED VALUES
24	24	240	4.86	240	0	8.5	9.506517382
24	24	240	4.86	240	24	10	8.659762992
24	24	240	4.86	240	48	10	7.813008601
24	24	240	4.86	240	72	8	6.966254211
24	24	240	4.86	240	96	5.5	6.119499821
24	24	240	4.86	216	0	8.5	8.929399163
24	24	240	4.86	216	24	9.5	8.124982492
24	24	240	4.86	216	48	9.5	7.320565821
24	24	240	4.86	216	72	8	6.51614915
24	24	240	4.86	216	96	6	5.711732479
24	24	240	4.86	192	0	8.5	8.352280943
24	24	240	4.86	192	24	9.5	7.590201992
24	24	240	4.86	192	48	9.5	6.82812304
24	24	240	4.86	192	72	7.5	6.066044089
24	24	240	4.86	192	96	6	5.303965138
24	24	240	4.86	168	0	7.5	7.775162723
24	24	240	4.86	168	24	8.5	7.055421492
24	24	240	4.86	168	48	8.5	6.33568026
24	24	240	4.86	168	72	7.5	5.615939028
24	24	240	4.86	168	96	6	4.896197796
24	24	240	4.86	144	0	7	7.198044504
24	24	240	4.86	144	24	8	6.520640992
24	24	240	4.86	144	48	8.5	5.843237479
24	24	240	4.86	144	72	7	5.165833967
24	24	240	4.86	144	96	6.5	4.488430454
24	24	240	4.86	120	0	7.5	6.620926284
24	24	240	4.86	120	24	8.5	5.985860491
24	24	240	4.86	120	48	9	5.350794699
24	24	240	4.86	120	72	6.5	4.715728906
24	24	240	4.86	120	96	4	4.080663113
24	24	240	4.86	96	0	8	6.043808065
24	24	240	4.86	96	24	9	7.451079991
24	24	240	4.86	96	48	10	7.858351918
24	24	240	4.86	96	72	6	4.265623845
24	24	240	4.86	96	96	2	2.672895771
24	24	240	4.86	72	0	7.5	5.466689845
24	24	240	4.86	72	24	8	6.916299491
24	24	240	4.86	72	48	7.5	5.365909137
24	24	240	4.86	72	72	5.5	4.815518784

24	24	240	4.86	72	96	3	3.26512843
24	24	240	4.86	48	0	6.5	4.889571625
24	24	240	4.86	48	24	6.5	4.381518991
24	24	240	4.86	48	48	5.5	3.873466357
24	24	240	4.86	48	72	4.5	3.365413723
24	24	240	4.86	48	96	3	2.857361088
24	24	240	4.86	24	0	5.5	4.312453406
24	24	240	4.86	24	24	5	3.846738491
24	24	240	4.86	24	48	4.5	3.381023576
24	24	240	4.86	24	72	3.5	2.915308662
24	24	240	4.86	24	96	2.5	2.449593747
24	24	240	4.86	0	0	1	3.735335186
24	24	240	4.86	0	24	4	3.311957991
24	24	240	4.86	0	48	3.5	2.888580796
24	24	240	4.86	0	72	3	2.465203601
24	24	240	4.86	0	96	2.5	2.041826405
24	24	240	4.86	-24	0	3	3.158216967
24	24	240	4.86	-24	24	3	2.777177491
24	24	240	4.86	-24	48	2.5	2.396138015
24	24	240	4.86	-24	72	2.5	2.015098539
24	24	240	4.86	-24	96	1	1.234059064
24	24	240	4.86	-48	0	1	1.181098747
24	24	240	4.86	-48	24	1	1.242396991
24	24	240	4.86	-48	48	1	0.903695235
24	24	240	4.86	-48	72	1	1.164993478
24	24	240	4.86	-48	96	1	1.226291722
24	24	240	4.86	-72	0	1	1.003980527
24	24	240	4.86	-72	24	1	0.707616491
24	24	240	4.86	-72	48	1	1.211252454
24	24	240	4.86	-72	72	1	1.114888417
24	24	240	4.86	-72	96	1	0.818524381
48	24	240	4.86	480	0	1	1.224452107
48	24	240	4.86	480	48	1	1.589386314
48	24	240	4.86	480	96	3	2.954320521
48	24	240	4.86	480	144	3	2.319254728
48	24	240	4.86	480	192	3	2.684188936
48	24	240	4.86	432	0	1	1.038773655
48	24	240	4.86	432	48	1	1.146045582
48	24	240	4.86	432	96	1	1.153317509
48	24	240	4.86	432	144	1	1.260589436
48	24	240	4.86	432	192	2.25	1.667861362
48	24	240	4.86	384	0	3.25	3.853095204
48	24	240	4.86	384	48	3	3.30270485
48	24	240	4.86	384	96	1	1.152314496

48	24	240	4.86	384	144	2.25	2.201924143
48	24	240	4.86	384	192	1.5	1.651533789
48	24	240	4.86	336	0	7	4.667416753
48	24	240	4.86	336	48	3.25	3.159364118
48	24	240	4.86	336	96	2.25	2.651311484
48	24	240	4.86	336	144	1.75	2.14325885
48	24	240	4.86	336	192	1	1.135206216
48	24	240	4.86	288	0	5	3.481738301
48	24	240	4.86	288	48	3.5	3.016023387
48	24	240	4.86	288	96	1.75	1.550308472
48	24	240	4.86	288	144	1.5	1.284593557
48	24	240	4.86	288	192	1	1.118878642
48	24	240	4.86	240	0	5	3.29605985
48	24	240	4.86	240	48	3.5	2.872682655
48	24	240	4.86	240	96	1.5	1.44930546
48	24	240	4.86	240	144	1.25	1.125928264
48	24	240	4.86	240	192	1.25	1.602551069
48	24	240	4.86	192	0	6	5.110381399
48	24	240	4.86	192	48	3.5	2.729341923
48	24	240	4.86	192	96	1	1.348302447
48	24	240	4.86	192	144	1	1.167262971
48	24	240	4.86	192	192	1	1.186223496
48	24	240	4.86	144	0	5	3.924702947
48	24	240	4.86	144	48	3.5	2.586001191
48	24	240	4.86	144	96	1.75	2.247299435
48	24	240	4.86	144	144	1.25	1.208597679
48	24	240	4.86	144	192	1.25	1.569895923
48	24	240	4.86	96	0	4.25	3.739024496
48	24	240	4.86	96	48	3.25	2.442660459
48	24	240	4.86	96	96	1	1.146296423
48	24	240	4.86	96	144	1.75	1.849932386
48	24	240	4.86	96	192	1.25	1.553568349
48	24	240	4.86	48	0	3.5	2.553346044
48	24	240	4.86	48	48	3	2.299319727
48	24	240	4.86	48	96	1	1.04529341
48	24	240	4.86	48	144	1.75	1.791267093
48	24	240	4.86	48	192	1.75	1.537240776
48	24	240	4.86	0	0	1	2.367667593
48	24	240	4.86	0	48	2.5	2.155978995
48	24	240	4.86	0	96	1	1.144290398
48	24	240	4.86	0	144	1	1.1326018
48	24	240	4.86	0	192	2	1.520913203
48	24	240	4.86	-48	0	1	1.181989142
48	24	240	4.86	-48	48	1	1.012638264

48	24	240	4.86	-48	96	1	1.143287386
48	24	240	4.86	-48	144	1	1.173936507
48	24	240	4.86	-48	192	1	1.104585629
48	24	240	4.86	-96	0	1	1.19631069
48	24	240	4.86	-96	48	1	1.169297532
48	24	240	4.86	-96	96	1	1.142284373
48	24	240	4.86	-96	144	1	1.115271215
48	24	240	4.86	-96	192	1	1.188258056
48	24	240	4.86	-144	0	1	1.110632239
48	24	240	4.86	-144	48	1	1.1259568
48	24	240	4.86	-144	96	1	1.141281361
48	24	240	4.86	-144	144	1	1.156605922
48	24	240	4.86	-144	192	1	1.171930483
24	24	240	5.88	240	0	5	5.653226036
24	24	240	5.88	240	24	4.75	5.074763359
24	24	240	5.88	240	48	4.5	4.496300681
24	24	240	5.88	240	72	3.75	3.917838003
24	24	240	5.88	240	96	3.25	3.339375326
24	24	240	5.88	216	0	5	5.288467675
24	24	240	5.88	216	24	4.75	4.738928131
24	24	240	5.88	216	48	4.75	4.189388587
24	24	240	5.88	216	72	3.75	3.639849043
24	24	240	5.88	216	96	3	3.0903095
24	24	240	5.88	192	0	5	4.923709313
24	24	240	5.88	192	24	5	4.403092903
24	24	240	5.88	192	48	4.75	3.882476493
24	24	240	5.88	192	72	3.75	3.361860083
24	24	240	5.88	192	96	2.5	2.841243674
24	24	240	5.88	168	0	5	4.558950951
24	24	240	5.88	168	24	5	4.067257675
24	24	240	5.88	168	48	4.75	3.575564399
24	24	240	5.88	168	72	3.75	3.083871123
24	24	240	5.88	168	96	2.5	2.592177847
24	24	240	5.88	144	0	5	4.194192589
24	24	240	5.88	144	24	4.75	3.731422447
24	24	240	5.88	144	48	4.75	3.268652305
24	24	240	5.88	144	72	3.5	2.805882163
24	24	240	5.88	144	96	2.5	2.343112021
24	24	240	5.88	120	0	4.75	3.829434228
24	24	240	5.88	120	24	4.25	3.39558722
24	24	240	5.88	120	48	3.5	2.961740211
24	24	240	5.88	120	72	2.5	2.527893203
24	24	240	5.88	120	96	1.75	2.094046195
24	24	240	5.88	96	0	4.5	3.464675866

24	24	240	5.88	96	24	3.5	3.059751992
24	24	240	5.88	96	48	2	2.654828117
24	24	240	5.88	96	72	1.5	1.249904243
24	24	240	5.88	96	96	1.5	1.844980369
24	24	240	5.88	72	0	4	3.099917504
24	24	240	5.88	72	24	3	2.723916764
24	24	240	5.88	72	48	2	2.347916024
24	24	240	5.88	72	72	1.5	1.971915283
24	24	240	5.88	72	96	1.5	1.595914543
24	24	240	5.88	48	0	3.25	2.735159143
24	24	240	5.88	48	24	2.5	2.388081536
24	24	240	5.88	48	48	2	2.04100393
24	24	240	5.88	48	72	1.5	1.693926323
24	24	240	5.88	48	96	1.5	1.346848717
24	24	240	5.88	24	0	2.5	2.370400781
24	24	240	5.88	24	24	2.25	2.052246308
24	24	240	5.88	24	48	1.75	1.734091836
24	24	240	5.88	24	72	1.5	1.415937363
24	24	240	5.88	24	96	1.5	1.09778289
24	24	240	5.88	0	0	1	1.005642419
24	24	240	5.88	0	24	2	1.716411081
24	24	240	5.88	0	48	1	1.227179742
24	24	240	5.88	0	72	1	1.137948403
24	24	240	5.88	0	96	1.5	1.848717064
24	24	240	5.88	-24	0	1	1.140884058
24	24	240	5.88	-24	24	1	1.180575853
24	24	240	5.88	-24	48	1	1.120267648
24	24	240	5.88	-24	72	1	0.859959443
24	24	240	5.88	-24	96	1	0.999651238
24	24	240	5.88	-48	0	1	1.276125696
24	24	240	5.88	-48	24	1	1.044740625
24	24	240	5.88	-48	48	1	0.813355554
24	24	240	5.88	-48	72	1	0.881970483
24	24	240	5.88	-48	96	1	0.850585412
24	24	240	5.88	-72	0	1	0.911367334
24	24	240	5.88	-72	24	1	0.708905397
24	24	240	5.88	-72	48	1	0.90644346
24	24	240	5.88	-72	72	1	0.703981523
24	24	240	5.88	-72	96	1	1.101519586
48	24	240	5.88	480	0	2.75	2.476272882
48	24	240	5.88	480	48	3	2.042425874
48	24	240	5.88	480	1	3.5	2.467234403
48	24	240	5.88	480	144	3	2.174731857
48	24	240	5.88	480	192	2.5	2.740884849

48	24	240	5.88	432	0	2.5	2.378927715
48	24	240	5.88	432	48	2.75	1.97400384
48	24	240	5.88	432	96	2.75	2.569079966
48	24	240	5.88	432	144	2.5	2.164156092
48	24	240	5.88	432	192	2.25	1.759232218
48	24	240	5.88	384	0	2.5	2.281582548
48	24	240	5.88	384	48	2.5	1.905581807
48	24	240	5.88	384	96	2.5	2.529581067
48	24	240	5.88	384	144	2	2.153580326
48	24	240	5.88	384	192	1.75	1.777579186
48	24	240	5.88	336	0	7	2.184237385
48	24	240	5.88	336	48	2.75	1.837159774
48	24	240	5.88	336	96	2	1.490082167
48	24	240	5.88	336	144	1.75	1.143004561
48	24	240	5.88	336	192	1.75	1.795926954
48	24	240	5.88	288	0	4.5	4.086892213
48	24	240	5.88	288	48	3	2.76873774
48	24	240	5.88	288	96	2	1.450583268
48	24	240	5.88	288	144	1.75	1.132428795
48	24	240	5.88	288	192	1.75	1.814274322
48	24	240	5.88	240	0	4.25	3.989547046
48	24	240	5.88	240	48	3	2.700315707
48	24	240	5.88	240	96	1.75	1.411084368
48	24	240	5.88	240	144	1.5	1.121853029
48	24	240	5.88	240	192	1.5	1.532621691
48	24	240	5.88	192	0	4	2.892201879
48	24	240	5.88	192	48	2.5	2.631893674
48	24	240	5.88	192	96	2	1.371585469
48	24	240	5.88	192	144	2	1.311277264
48	24	240	5.88	192	192	1.5	0.950969059
48	24	240	5.88	144	0	3.25	2.794856711
48	24	240	5.88	144	48	2.25	1.56347164
48	24	240	5.88	144	96	1.5	1.332086569
48	24	240	5.88	144	144	1.5	1.100701498
48	24	240	5.88	144	192	1.75	1.869316427
48	24	240	5.88	96	0	2.75	2.497511544
48	24	240	5.88	96	48	2.25	1.495049607
48	24	240	5.88	96	96	2	1.29258767
48	24	240	5.88	96	144	2	1.590125733
48	24	240	5.88	96	192	2	1.887663796
48	24	240	5.88	48	0	2.5	1.600166377
48	24	240	5.88	48	48	1	1.226627574
48	24	240	5.88	48	96	1	1.25308877
48	24	240	5.88	48	144	1	1.079549967

48	24	240	5.88	48	192	2.5	1.906011164
48	24	240	5.88	0	0	1	1.30282121
48	24	240	5.88	0	48	1	1.25820554
48	24	240	5.88	0	96	2.5	1.513589871
48	24	240	5.88	0	144	2.75	2.068974202
48	24	240	5.88	0	192	3	2.924358532
48	24	240	5.88	-48	0	1	1.205476042
48	24	240	5.88	-48	48	1	1.289783507
48	24	240	5.88	-48	96	2.75	1.274090971
48	24	240	5.88	-48	144	3.25	3.058398436
48	24	240	5.88	-48	192	4	2.9427059
48	24	240	5.88	-96	0	1	1.308130875
48	24	240	5.88	-96	48	1	1.221361474
48	24	240	5.88	-96	96	2.75	2.134592072
48	24	240	5.88	-96	144	3.5	2.04782267
48	24	240	5.88	-96	192	4.5	2.961053269
48	24	240	5.88	-144	0	1	1.210785708
48	24	240	5.88	-144	48	1	1.15293944
48	24	240	5.88	-144	96	2.75	2.095093172
48	24	240	5.88	-144	144	3.75	2.037246905
48	24	240	5.88	-144	192	4.5	3.979400637