Analysis of Influence Factor for Compressive Strength in Plastic Induced Concrete

Effect of Plastic Coarse Aggregate in Concrete

[1]Yash Lohana, [2]Sourabh Patil

[1]Assistant Engineer, [2]PG Student,
[1]Civil Project Office – SGI,
[1]Sanjay Ghodawat Group, Kolhapur, India.

Abstract: This paper exhibits the experimentation of partially replacing plastic coarse aggregates in the concrete, obtain the results and interpret it to get a generalized statement. This concept proposes an approach which can contribute towards nature by consuming plastic and serve the industry better as well as stay competitive in the market but its application is still not seen widely in general practice. Various causes and effects which are responsible for non-acceptance of this concept within the construction industry must be understood. In this study, the compressive strength of concrete with partially substituted plastic aggregates is prioritized.

***Index Terms* – Plastic Coarse Aggregate, Influence Factor, Compressive Strength.**

I. INTRODUCTION

Plastic exposure in environment is recognized as an issue of significance. The construction industry recognizes a variety of approaches to reduce the use of stone and sand. The plastic becomes a potential substitute to the coarse aggregates due its properties as a potential construction material. In the merit, the manufacture of this coarse aggregate is possible with the recyclable waste plastic. Thus, creation of plastic is not needed as the existing plastic can be recycled and consumed.

Plastic used to make aggregates have flexibility to modify its attribute such as that required by natural aggregates. Use of the plastic aggregates tend to make the concrete more ductile, it improves its performance when high expansion and contraction is expected. Plastic aggregates having less density, helps to produce light weight concrete. Other than being chemically inert, it is insulating thermally and electrically. It is not only cost effective and competitive in the market but also environmental friendly.

Due to many such reasons, it becomes compelling to understand if such substitution is feasible or not. If the industry wide process of successfully utilizing the plastic as a feedstock in the production of concrete as a product is inciting from environmental, economic and technological perspective.

II. CONCEPT

This report deals with an approach of partially substituting the plastic coarse aggregates with natural coarse aggregates in various proportions to understand the variations in the effect of such substitution and its relation. This relation depends on the bonding of cement and the aggregate. The cement binds with both natural and plastic aggregates but the bond strength varies. The bond strength also depends on the water cement ratio of concrete, size of aggregates, grade of cement used. The variations in the results are obtained as these properties vary. Assuming the quality of materials is as per the specification, the results will indicate the expected results. Understanding the nature of these variation and the correlation of the properties due to which this nature of variation occurs is the purpose of this study.

The variations observed incur due to different properties of natural aggregates and plastic aggregates. The interaction of these aggregates with other materials in the concrete viz. cement and water, varies due to these difference in properties. The extent up to which these varying interaction is beneficial is an important factor in this study. This extent is observed for every property of the concrete. Variation in the pattern of these extents with change in parameters is observed and studied in order to understand the nature of this behavior of the concrete.

The nature of this behavior gives the relation for a specific property of concrete under the specified conditions. This relation determines if such conditions are suitable for implementation or not. It also determines which conditions make such implementations suitable. This study deals with the nature of variation in compressive strength due to change in the proportion of aggregate substitution.

III. AGGREGATES

According to IS 2386-1963 and IS 383-1970, the specifications of the aggregates made from plastic are stated as mentioned

i. Natural Aggregates:

The specifications stated comply with the properties of naturally occurring stone

- Specific Gravity: 2.74
- Crushing Value: 28
- Density: 3.1

Natural Aggregates are obtained from the stone mining. The physical properties and geological properties of these stones and its impact as aggregate in concrete are significant. Coarse Aggregates formed from these stones have the standard size and shape as mentioned in the IS Code

ii. Plastic Aggregates:

The specifications stated comply with the properties of aggregates formed by the standard process as specified

- Specific Gravity: 0.9
- Crushing Value: 2

- Density: 0.81

Plastic Aggregates formed to attain the above mentioned properties are developed by the following process which include.

i. Chemical Modification
ii. Mechanical Recycling
iii. Thermal Processing
iv. Filler Process

Understanding the above mentioned processes

i. Chemical Modification: The process is also known as De-polymerization. It involves two methods as mentioned
   a. Hydrolysis (Chemical Decomposition)
   b. Pyrolysis (Thermal Decomposition)

ii. Mechanical Recycling: It involves Melting and Shredding or Granulation. The plastic must be sorted prior to this process in to the following
   a. HDPE: High Density Poly-ethylene
   b. TPO: Thermoplastic Polyolefin

iii. Thermal Processing: A thermoplastic material is heated to change its physical properties by modifying its structural arrangement. The process involved melting it into a liquid by heating and then cooling.

iv. Filler Process: The waste from this process can be used as fillers in variety of materials including Virgin Resins, Concrete or Bitumen

The product obtained after these processes are considered as plastic aggregates. The physical properties and chemical properties of these stones and its impact as aggregate in concrete are significant. Coarse Aggregates formed from these stones have the standard size and shape as mentioned in the IS Code.

IV. Scope of Study:

The concept describes that interaction of a material with other materials and their correlation depends on the nature of variation. This interaction should be till the extent which is beneficial in regard to the a specific property considered. Major strength related properties include

i. Compressive Strength
ii. Flexural Strength
iii. Split Tensile Strength

These properties may exhibit different nature of change and extend of this change under the similar conditions. A property may exhibit an increase or decrease in strength up to an extent under the given condition.

The relation between the quantity of partially substituted plastic aggregates in concrete and the rate of change in the strength is studied to understand this nature of change in the strength due to substitution. This gives information which can be used to state the nature of change. It also gives the rate at which the change occurs.

The increase in strength indicates a strong bond of the given nature and similarly, the decrease in strength indicates a weak bond of the given nature. This behavior with respect to the property and material under consideration must be studied to understand the behavior of the concrete due to partial substitution of plastic aggregates for the same. It is to be conducted for partial substitution of plastic in concrete.

Such experimentation will give the results which can be interpreted to verify the concept. The difference in the result of the samples with the various specifications will also give the extent of the effects on various parameters. Once the concept of the thesis is verified and the implications are also tested then the implementation of the same in a large scale can be considered.

Verification of the thesis involves the experimentation for testing of the compressive strength for various grades of mix design strength with the different proportions of substitution. It is expected that the variation in the nature of concrete properties will occur due to partial substitution of coarse aggregates. So the obtained results from the experimentation can be used to compute the following results

1. The relation of the change in strength of concrete and proportion of partially substituted plastic coarse aggregates
2. The nature of the change in strength of concrete for change in parameters
3. The rate of change of the strength in the concrete for the change in proportion of aggregate substitution
4. The rate of increase of the strength in the concrete for the change in grade of concrete

In this paper, results for the property of compressive strength is obtained and studied.

V. Experimentation:

Following are the experimentation carried out to study the variations

1. The concrete with a selected grade is tested for increase in strength for different proportions of substitution
2. The concrete of varying mix design grade is tested for increase in strength for a constant proportion of substitution
3. The iteration of the values of the strength of other grades of concrete under consideration and the proportions of substitution is conducted

In the first experiment, the M20 of concrete is chosen to test the strength increase with varying proportion of substitution of plastic coarse aggregate in 1000 base points, 2000 base points, 3000 base points and 4000 base points for weight of concrete.

In the second experiment, strength test is carried out for M20, M30 and M40 grade of concrete mix design for substitution of 0 base points and 1000 base points for weight of concrete.

In the third experiment, iterations are conducted with the results obtained from the above two experiments to calculate the values of other concrete specifications within the parameters of concrete grade M20, M30 and M40 and substitution proportion of 2000 base points and 3000 base points.

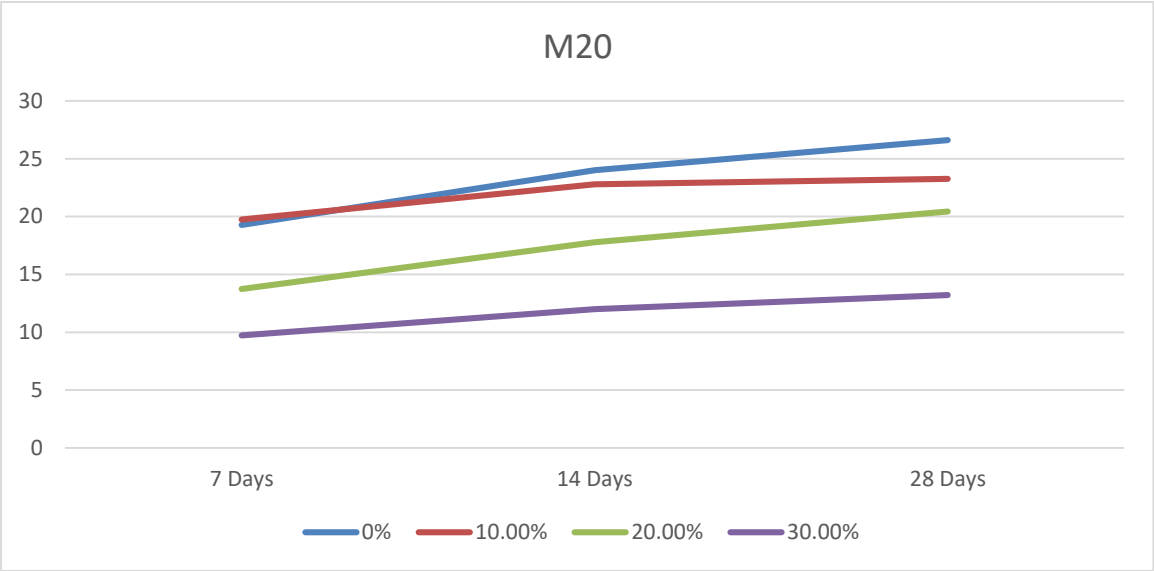
VI. Results Obtained:

The results from the above mentioned three experiments is given in the following tables for each grade and these results are shown in graphical form

1. M20 Concrete

Days	Compressive strength of M20 at various proportions of substitutions			
	0%	10%	20%	30%
7	19.28667	19.755	13.75	9.74
14	24.02	22.7	17.785	12.035
28	26.61667	23.25	20.44	13.22

Table 1: Compressive Strength of M20 Concrete samples of substitution

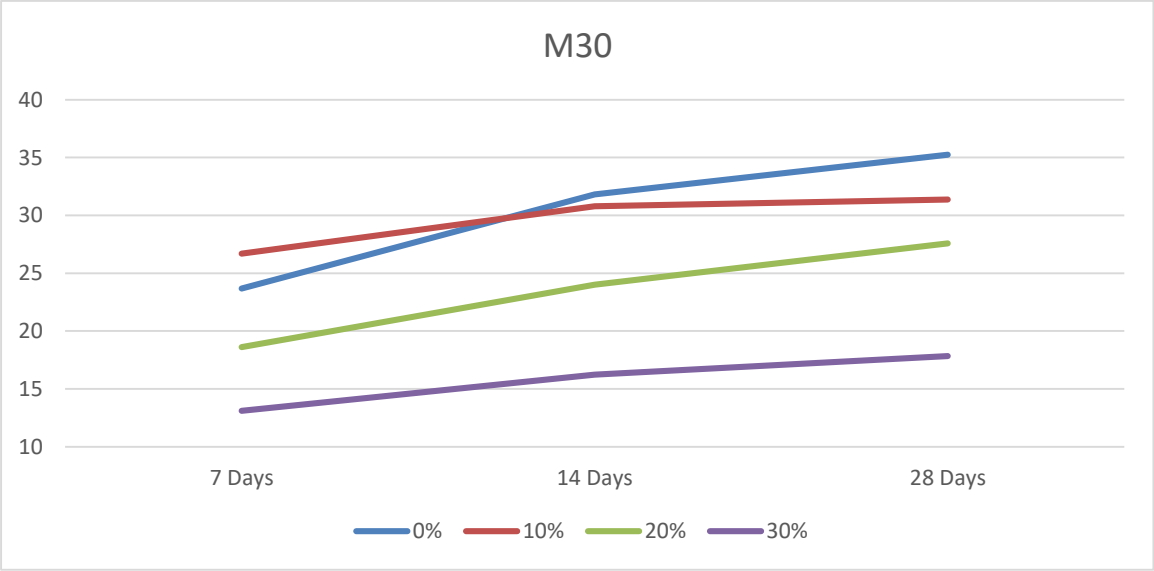


Graph 1: Various proportions of substitution for M20 grade concrete

2. M30 Concrete

Days	Compressive strength of M30 at various proportions of substitutions			
	0%	10%	20%	30%
7	23.67	26.8	18.61	13.1
14	31.825	30.78	24	16.24
28	35.25	31.38	27.59	17.84

Table 2: Compressive Strength of M30 Concrete samples of substitution

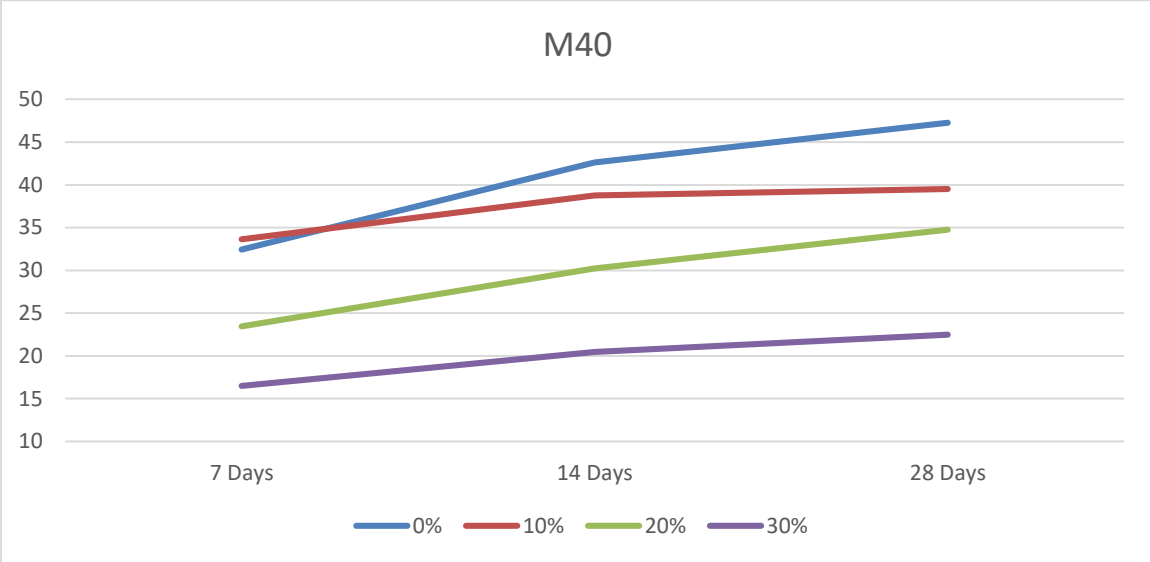


Graph 2: Various proportions of substitution for M30 grade concrete

3. M40 Concrete

Days	Compressive strength of M40 at various proportions of substitutions			
	0%	10%	20%	30%
7	32.43	33.64	23.44	16.5
14	42.625	38.78	30.24	20.46
28	47.28	39.53	34.76	22.47

Table 3: Compressive Strength of M40 Concrete samples of substitution



Graph 3: Various proportions of substitution for M40 grade concrete

VII. Analysis Of Results:

The analysis of the above results is conducted by obtaining the values of influence factor at every stage of influence. The difference of these influence factors gives the relationship between the factors at different proportions of substitution. The influence factor is obtained from the influence plane which can be formed by the determinant of the matrix for different proportions of substitution.

The values of strength gain by the concrete test cubes due to substituted proportion of aggregate for given design grade of concrete at standard period of curing is represented by a 3D matrix. Such a matrix is known as Matrix of Influence. The matrix obtained from the above results would represent the compressive strength of specified grades of concrete influenced by the partial substitution of plastic aggregates

- The strength of the matrix of Influence is given by

$$3D\ Matrix\ of\ Influence_{(Duration,\ Grade,\ Proportion)} = [IF\ Matrix]_{3*3*4} = 36$$

Equation 1

- This matrix is written as

$$[7d \quad 14d \quad 28d]\begin{bmatrix} M20 \\ M30 \\ M40 \end{bmatrix}[0\% \quad 10\% \quad 20\% \quad 30\%]$$

$$= \left\langle \begin{bmatrix} 19.28 & 19.75 & 13.75 & 9.74 \\ 24 & 22.7 & 17.785 & 12. \\ 26.6 & 23.25 & 20.44 & 13.22 \end{bmatrix} \begin{bmatrix} 23.67 & 26.8 & 18.61 & 13.1 \\ 31.825 & 30.78 & 24 & 16.24 \\ 35.25 & 31.38 & 27.59 & 17.84 \end{bmatrix} \begin{bmatrix} 32.43 & 33.64 & 23.44 & 16.5 \\ 42.28 & 38.78 & 30.24 & 20.46 \\ 47.28 & 39.53 & 34.76 & 22.47 \end{bmatrix} \right\rangle$$

- To find the influence of different proportion we take determinant of the Influence factor for different proportions and vis-a-vie for other parameters

$$IF_{Proportions} = D_{(Duration,\ Grade)} = \left| \frac{[IF\ Matrix]_{3*3*4}}{[Proportion\ Array]_{1*4}} \right| = |IF\ Plane|_{3*3}$$

Equation 2

- The IF Plane obtained from the above expression shows the change in strength for a given proportion of substitution of concrete. We get an IF Plane for each of the proportion substituted. For 4 substitutions as mentioned above, we get 3D Graphs
  - 0% IF Plane

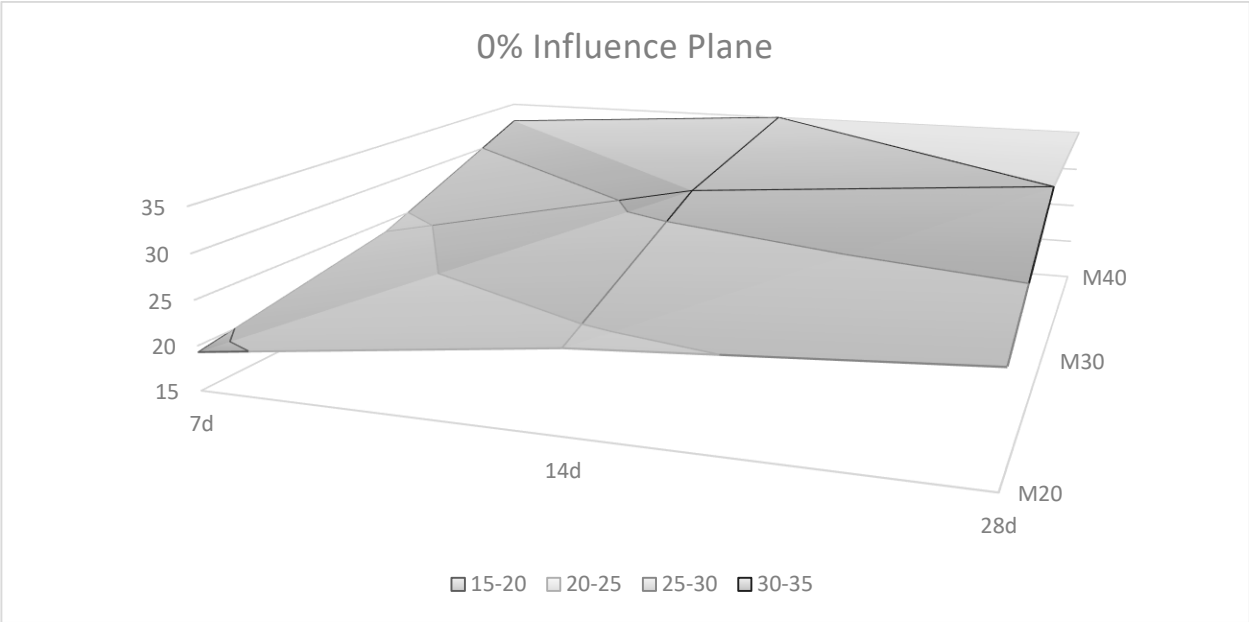


Figure 1: 0% Influence Plane

- 10% IF Plane

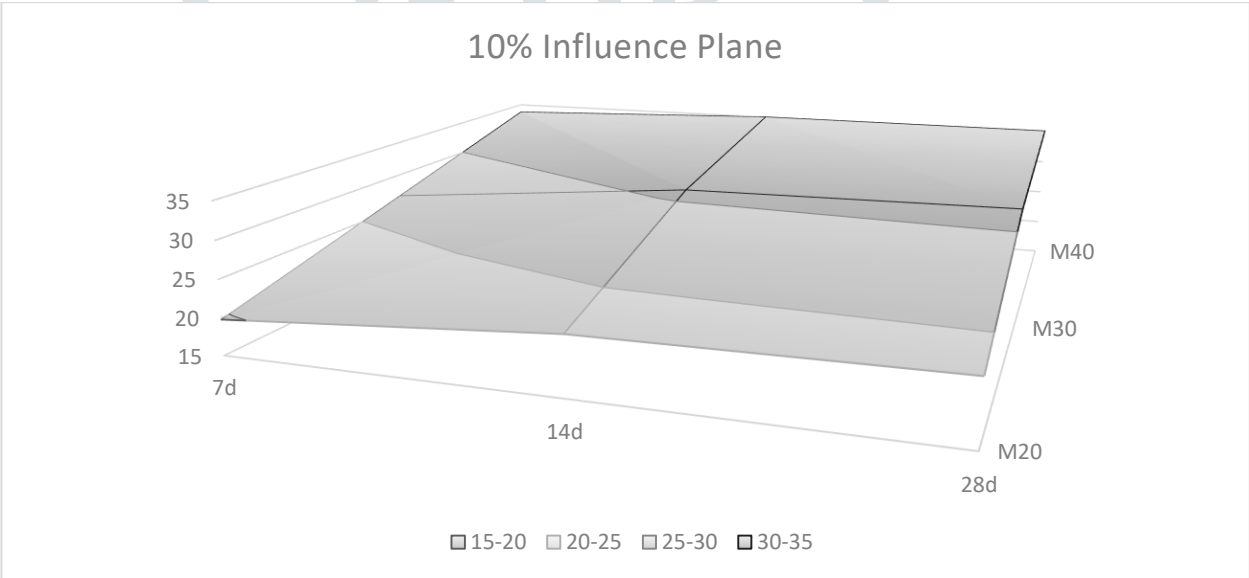


Figure 2: 10% Influence Plane

- 20% IF Plane

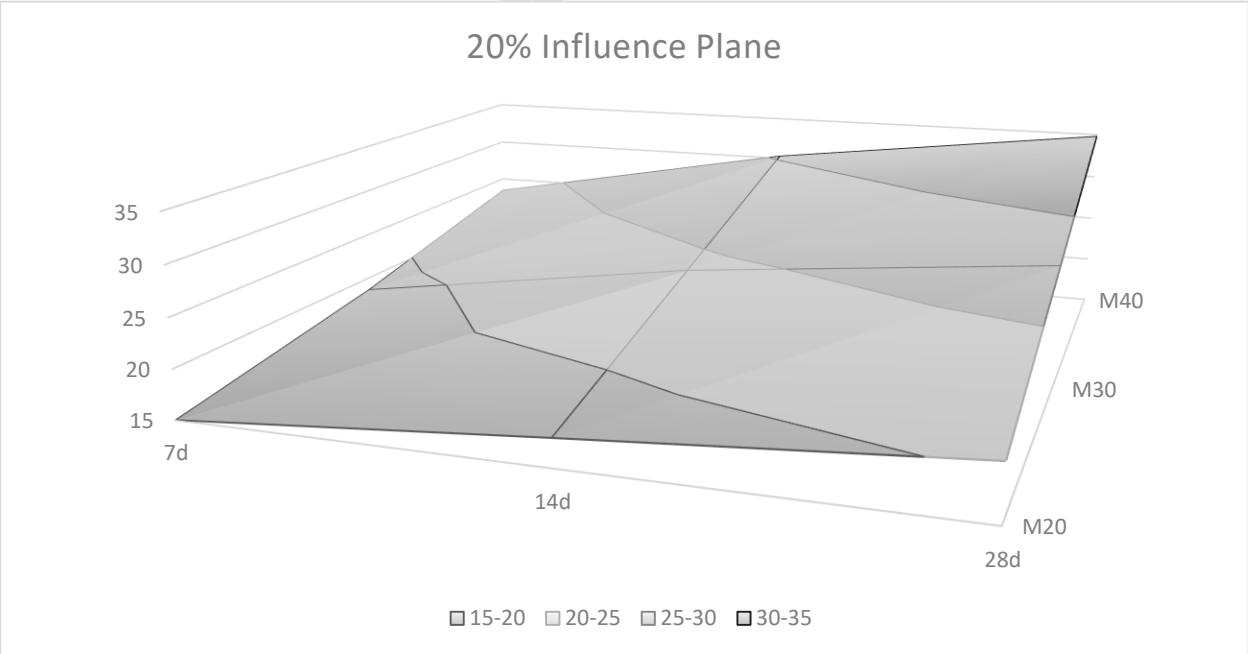


Figure 3: 20% Influence Plane

- 30% IF Plane

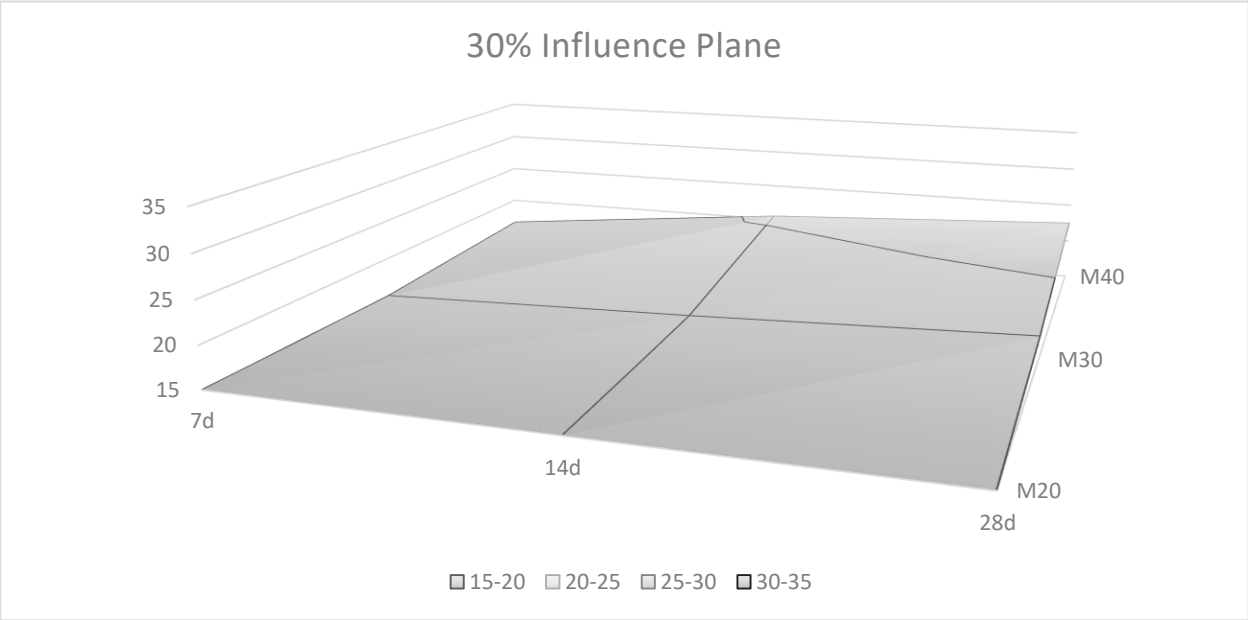


Figure 4: 30% Influence Plane

The Influence Plane obtained for each proportion of substitution indicates the intensity of the influence in terms of compressive strength of concrete blocks.

- From the observed result, it is depicted that the nature of the strength gain is same irrespective of the grade of concrete in which the specified proportion of substitution is considered

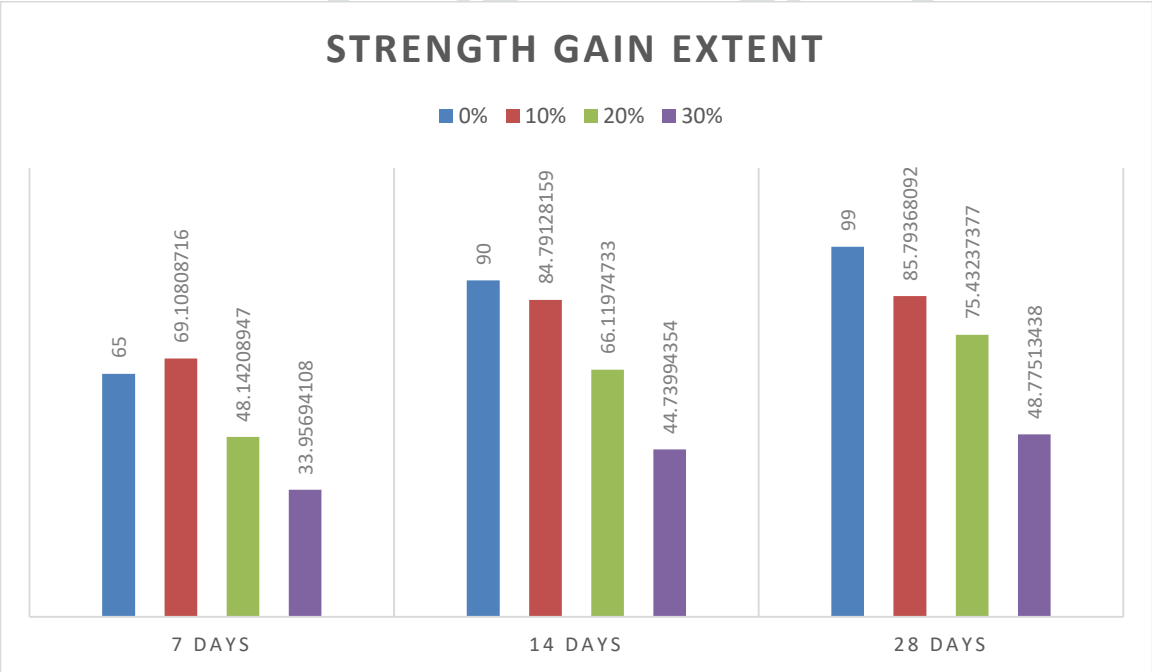


Figure 5:Strength Gain Extent

The strength growth curve for the different proportions of substitution is represented in the percentage gain of the strength as a generalized reference in the chart mentioned

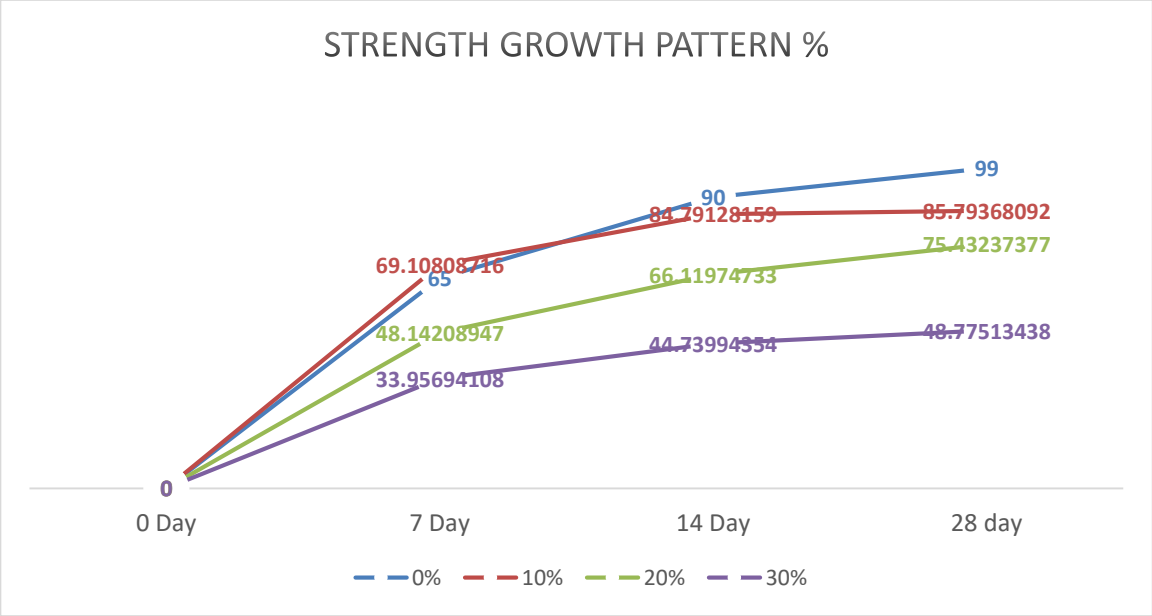


Figure 6: Strength Growth Pattern

The curve shows the trend which is followed by the total growth in strength below with respect to time

- The strength of various grades of concrete at various stages of time of its strength gain for the specified substitution are used to form a determinant which when solved gives the influence factor represented by (IF x)
  This influence factor indicates the influence of the specified substitution for various grades of concrete. The relative difference between the influence factors gives the intensity of the influence between the different proportions of substitution

$$(IF_{n+1}) - (IF_n) > 0$$

Equation 3

If $(IF_{n+1}) - (IF_n) > 0$ then, (IF_{n+1}) is more influencing else (IF_n) is more influencing. The values of influence factors are very sensitive. The values of the influence factor is calculated for each stage of influence

- D1 = Influence at 0% Substitution

$$D1 = \begin{bmatrix} 19.3 & 23.67 & 32.43 \\ 24.02 & 31.8 & 42.63 \\ 26.62 & 35.25 & 47.28 \end{bmatrix} = 1.26387$$

- D2 = Influence at 10% Substitution

$$D2 = \begin{bmatrix} 19.76 & 26.8 & 33.64 \\ 22.7 & 30.8 & 38.8 \\ 23.25 & 31.4 & 39.53 \end{bmatrix} = 0.52824$$

- D3 = Influence at 20% Substitution

$$D3 = \begin{bmatrix} 13.75 & 18.61 & 23.44 \\ 17.79 & 24.00 & 30.24 \\ 20.44 & 27.59 & 34.76 \end{bmatrix} = 0.001356$$

- D4 = influence at 30% Substitution

$$D4 = \begin{bmatrix} 9.74 & 13.10 & 16.50 \\ 12.04 & 16.24 & 20.46 \\ 13.22 & 17.84 & 22.47 \end{bmatrix} = -0.003024$$

- The obtained values of determinant can give the relationship of influence between the respective proportions of substitution in the concrete. This relationship can be obtained by either taking the difference between the factors or by taking the determinants of factors. To find the relationship of influence by the method of solving determinants there are 6 combinations possible. These combinations can be solved by both the methods. The difference between the influences to determine this relationship is iterated for each combination. We have considered the linear increase in proportion of substitution present for this calculation

1. $D4 - D1 = -1.266894$
2. $D3 - D1 = -1.262514$
3. $D2 - D1 = -0.73563$
4. $D4 - D2 = -0.531264$
5. $D3 - D2 = -0.526884$
6. $D4 - D3 = -0.00438$

The values obtain after calculating the difference is expressed above for each permutation of the influence factor calculated. This influence factor shows the nature of interaction of the influence plane among each other. The interaction and the co-relation is interpreted from these values

VIII. Interpretation Of Results:

The interpretation of the results can be realized by graphical and analytical methods. Both the methods are supposed to give the same interpretation. These interpretations can be expressed in the form of the relationships which would be derived from the obtained results within the extremities.

The result will determine whether the rate of increase in strength is linear or non-linear with respect to proportion of the substitution. This will allow iterating the value of change in the strength for different grades of concrete for the specified proportion of the same. A check is possible by testing the results of the strength for other variations as well.

If the relationship is linear then it is concluded that the relationship is established and the rate of variation observed in the final result. The rate of variation can be tested for different grades of concrete and the result is concluded.

If the relationship is not linear then it is concluded that the relation between the rate of increase in strength and the proportions of the substitution is not established. In this case the non-linear relationship which is obtained is considered and applied for all the grades. The test for determining this non-linear relationship is carried out by further experimentation. This reverse approach is tested to check whether the rate of increase in strength is depended on the proportion of substitution or it is independent of the factor under consideration. After the verification of the obtained values with experimentation this non-linear obtained relation is verified and considered to be standard for all the grades of concrete.

With both the approaches mentioned, the graph is plotted and the common points are taken to find the proportion in terms of area which gives the percentage of substitution needed for effective strength gain. Various optimization techniques can also be used to find the range of most probable occurrence and refinement in the obtained result.

The determinant formed from the rows representing proportions of the substitution and columns representing the grade of concrete will give the factor of influence of substitution of the plastic coarse aggregates in the concrete. This factor can give the universal limit of implementation to describe

1. The increase in strength of concrete for proportion of substitution irrespective of the grade
2. The proportion ratio to iterate the decrease in cement content for a reduction in cement due to increased proportion of substitution

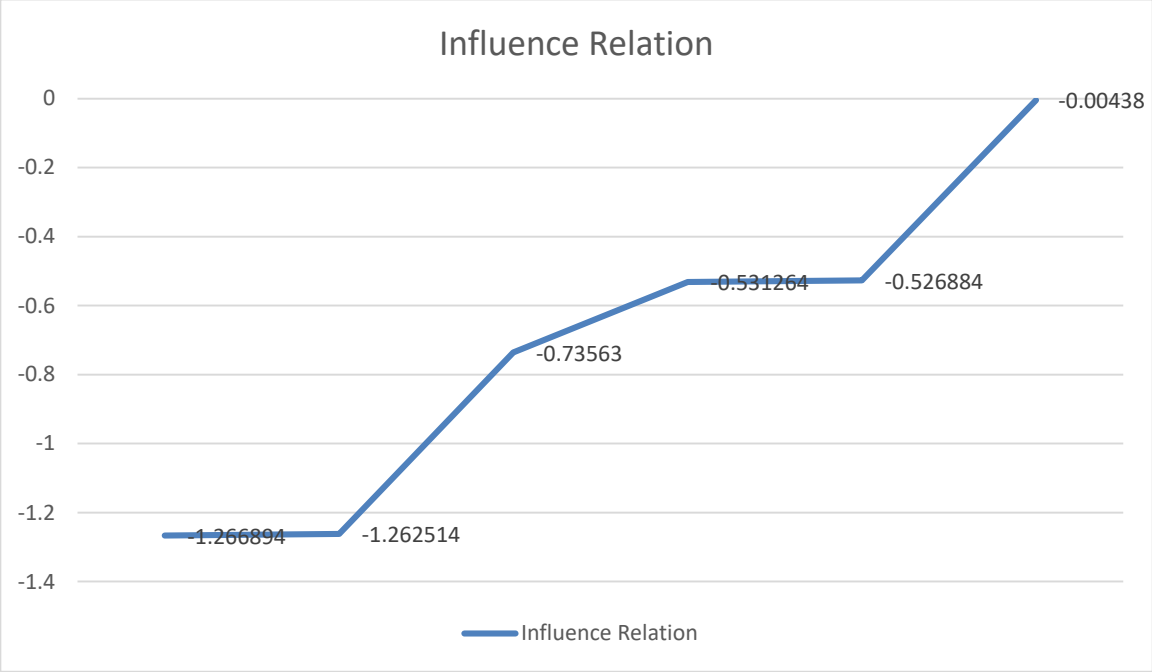


Figure 7: Influence Chart

In the family of curves of the strength gain of concrete with respect to time for different grade of concrete, the gradient of influence in the z-axis is given in the above influence chart.

The curve shows that the strength is increased gradually but the rate of change is steep and this shows that there is decrease in bond strength with increase in concentration of the substituted material. Thus it is concluded that to get a desired strength the design strength must be more as the efficiency of bond is reduced with high concentration of the substitution

IX. Conclusion And Significance:

Various conclusions are obtained from the above mentioned research

1. The amount of the plastic aggregates consumed by concrete is possible to state with certainty and thus the Influence Factor can be obtained. This approach is accepted and recommended if the Influence Factor is greater than unity
2. The range for various grade of concrete is obtained for the Influence Factor. Thus, the window of feasibility is obtained
3. Verification of the thesis is carried out and it is found that the influence factor is dependent on the amount of the substitution proportion of plastic aggregates in the concrete
4. Relationship between the rate of increase in the strength and the proportion of substitution is verified and interpreted
5. Value of the factor of influence of substitution of plastic coarse aggregates in concrete is obtained

X. Future Scope:

The future scope is given below

1. Industrial scale experiments assessed the feasibility of adding gaseous carbon dioxide to a ready mix production cycle in order to achieve beneficial sequestration of carbon dioxide in the concrete is also allowed
2. The fresh properties were impacted such that additional mix water may be required to reach the target slump but at the expense of slightly decreasing the compressive strength. Alternatively, the mix water can be unchanged and lower slump can be addressed through admixture addition prior to placement

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