Flow Variations due to damage in Irrigation Structures

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ABSTRACT
Seepage in different kinds of irrigation and water-retaining structures is dependent on various parameters like material and shape of structure, status like whether full or empty or partial and also their age and characteristics. Though inspection and drainage galleries in major dam structures account for this seepage, damage and distress either in the body or on the interface of the structures can make major changes in the flow and this study focuses attention on the role of crack or flaw within the body of the structure. Based on two-dimensional finite element discretisation and standard flow equation, a parametric study on location and size of flaw on the flow variations is done to assess the changes. Using a basic rectangular domain model to validate, case studies for velocity changes and flow pattern are given to highlight the role of damage and distress in such types of structures. These will form the basis for actual dam cross-sections for gravity, earthen and masonry type of materials which are quite popular in India.

Key Words

Finite element method , Fissures , Flow variation , Domain , Flow pattern , repair

1. INTRODUCTION

In irrigation structures, seepage through the body wall and foundation play a major role for the assessment of failures in the structures. To design any kind of structure for the proper irrigation, the effect due to seepage should be considered widely. Many methods have been suggested for the prediction of seepage. Dams and water retaining structures over a period of time develop distress in the form of fissures and cracks either in the body or on the surface . The fissures or cracks due to the different levels of water retained creates the seepage in the medium. The flow of seepage gets affected resulting in different pressures within the body of the domain. The present study is a focus on the effects flow while the flaw is assumed at various location . Impact over the velocity of the flow while the flaw of different size is assumed to be.

2. BASIC STUDIES

Initially a rectangular model of the domain is considered and a rectangular flaw is introduced as shown in Fig.1. The length to width ratio of the rectangle is taken as L : L/5, to reflect the base structure. Typical domain discretisation using triangular elements is shown for one typical model in Fig.2. Since finite element models depend on type of fineness and locations of element studies, refinements were done in three levels and convergence study for one case is shown in Fig.3 for three meshes M1,M2 and M3. Refinement M2 was chosen for further studies. Flaw or damage R2 is considered rectangular in shape and of area 1% of the domain and studies are done for various sizes at various locations.

Fig 1, Model of Rectangular Domain with Flaw

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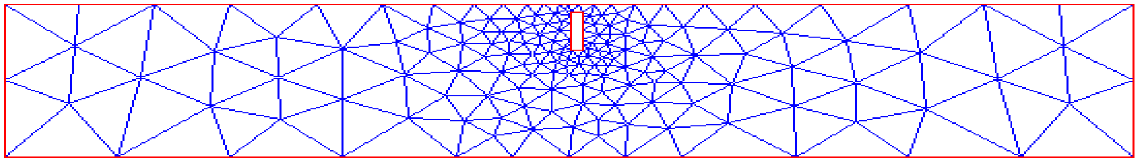


Fig 2, Finite element model of domain-mesh type M1

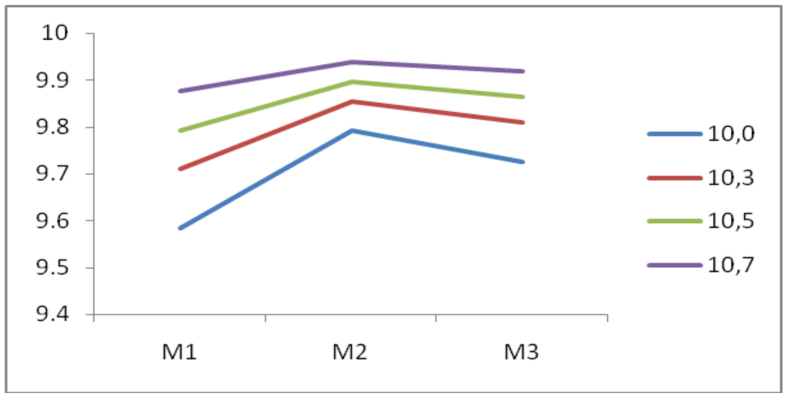
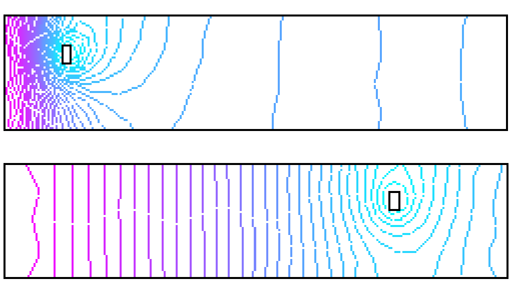


Fig 3 , Convergence studies for three different mesh types

3. RESULT AND DISCUSSION

3.1 VELOCITY VARIATIONS IN THE DOMAIN

The velocity variations within the domain are shown for two cases in Fig.4 for the same flaw size at locations near the upstream and one at the downstream. The contours indicate changes in the flow pattern due to location of damage or flaw in the domain. Hence it is preferable a study on location, size of flaw and different upstream water levels is conducted to get a clear idea of the effects on seepage so that repair and remedial measures could be initiated.



a) Flaw location near upstream at 0.3L
b) Flaw location downstream at 0.7L

Fig.4 Velocity variations due to flaw in the domain

To study the velocity variations of the seepage in the domain, parameter studies were conducted for

a) Location of flaw keeping size of flaw constant
b) Different upstream and downstream water levels given by velocity ratios
c) Size of flaw keeping critical location as constant
d) Flaw within and on the boundary of the domain
e) Different materials of the domain

3.1.1 FLAW OF SIZE RATIO 1:1

The results are given for critical ones in terms of graphs for better appreciation and inference. Fig. 5 gives the velocity variations for different locations keeping the size of flaw constant at 1:1 and the velocity of upstream/downstream ratios chosen as 10/0(no seepage), 10/3,10/5 and 10/7 to reflect different materials.

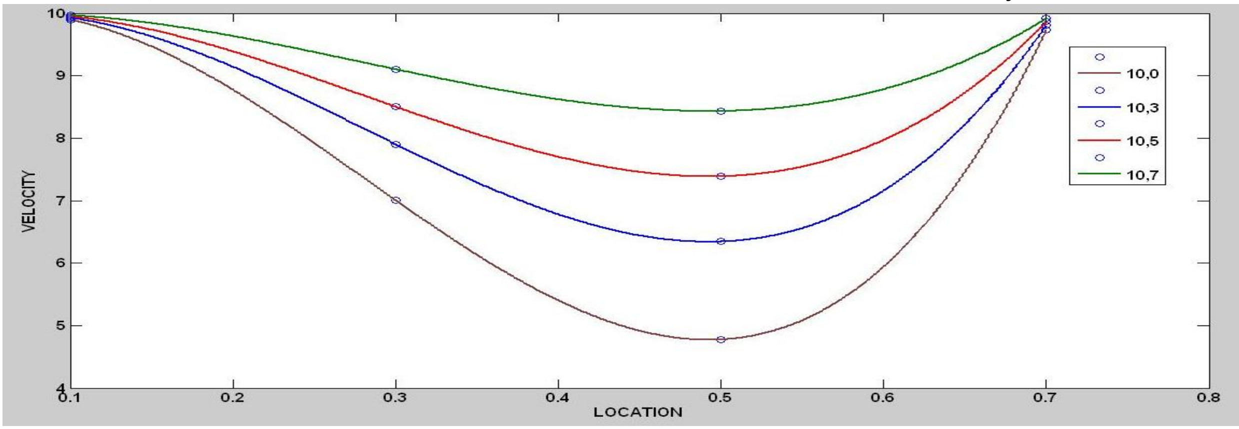


Fig 5 , Seepage analysis of the flaw of Size ratio 1:1

In Fig 5 , flaw size ratio 1:1 is considered for seepage analysis . The flaw is assumed to be at different locations. While the flaw is assumed at the center of the domain i.e., at 0.5L, the velocity taken by the domain is minimum and it slowly moves from the upstream side. For the entire length of the domain , the profile of the curve is non linear. Since the size is very small when the flaw is at 0.1L and 0.7L the domain admits more or less same velocity. While the flaw is at 0.3L the increment in the velocity is less than one and at 0.5L it shows the increment in the velocity more than 1.To overcome this difficulty and to find the exact deviation ,the entire set of values are normalized with the first location 0.1L. When the values are normalized , the velocity of the domain while the flaw is at 0.7L will be nearer to 1 and fits for the model. The locations 0.3 L and 0.5 L give the mean values as 81% and 67% respectively Normalised values give the simple entity from the complex entity. The percentage of increase is shown in Fig.6.While the flaw is at various locations and the distance of the flaw increases from the upstream edge , if the percentage of the seepage increases , there is a drop in the increase in velocity. But , at the farther location there will not be any remarkable drop and more or less same in all range of output. At the center of the domain , if the flaw is assumed , it will tend a decrement in velocity to the flaw at 0.7L.

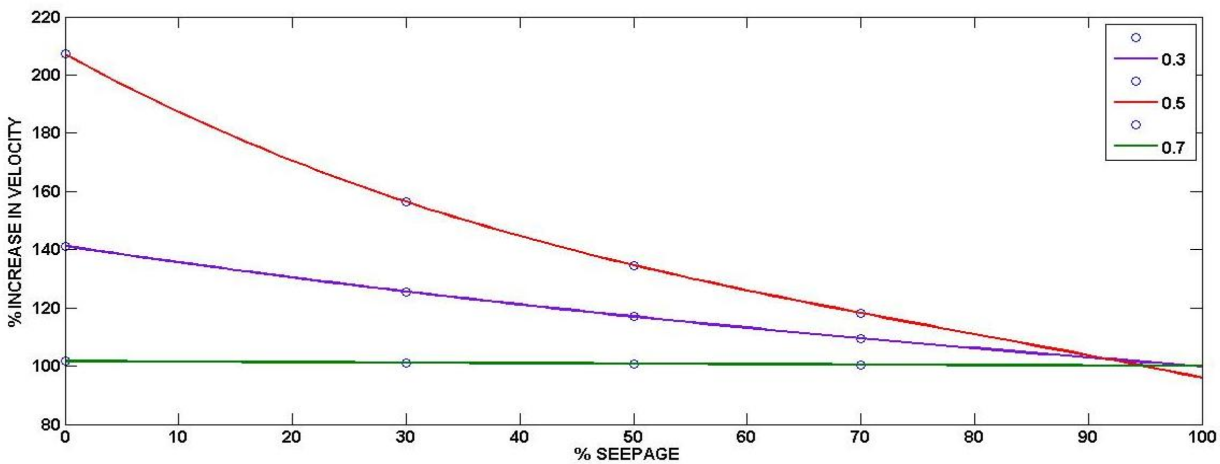


Fig 6, Percentage of Increase in velocity for the flaw size 1:1

3.1.2 FLAW OF SIZE RATIO 1:3

In the Fig 7, flaw size ratio 1:3 is considered for seepage analysis .

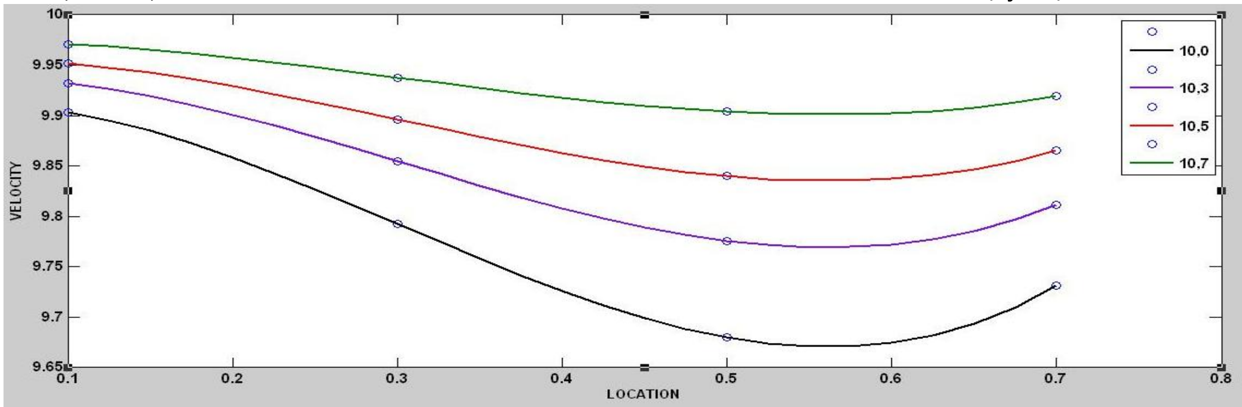


Fig 7 , Seepage analysis while the flaw of size ratio 1:3 at various location

Same as the previous case , while the flaw is at the center of the domain, takes less velocity compare with other locations. Also it is found that the seepage curve is non linear. While the output is 0% ,the difference between each location is between 0.05 and 0.11. If the output is 30% ,50% and 70% the difference is between 0.03 and 0.07 , 0.02 and 0.05 , 0.01 and 0.05 respectively. So, if the percentage of the output increases there is a decrease in velocity towards the outlet.

While the flaw is at 0.1L , the domain takes maximum velocity and it gradually decreases when the flaw is at the center of the domain ie at 0.5 L. Again it started increasing towards the downstream side of the structure. At the outlet definitely it will be maximum. Since the depth of the flaw is more it stops the water at the center and collects through the narrow route at the bottom of the flaw and send it to the outlet. The cross section below the flaw is small it collects easily the seepage and spread over to the right side of the flaw. Normalised values clearly show the velocity is approximately equal to 1 as per the theory of normalization. While the flaw is at the center the domain takes less velocity as previous case. And the percentage of the normalized velocity is tabulated and drawn against the location of the flaw. From the Fig 8, it is understood that the normalized velocity values give the more percentage of velocity when no output is assigned. The average percentage of normalized velocity is also with the values at 0.5L approximately equal to 101% for all the cases

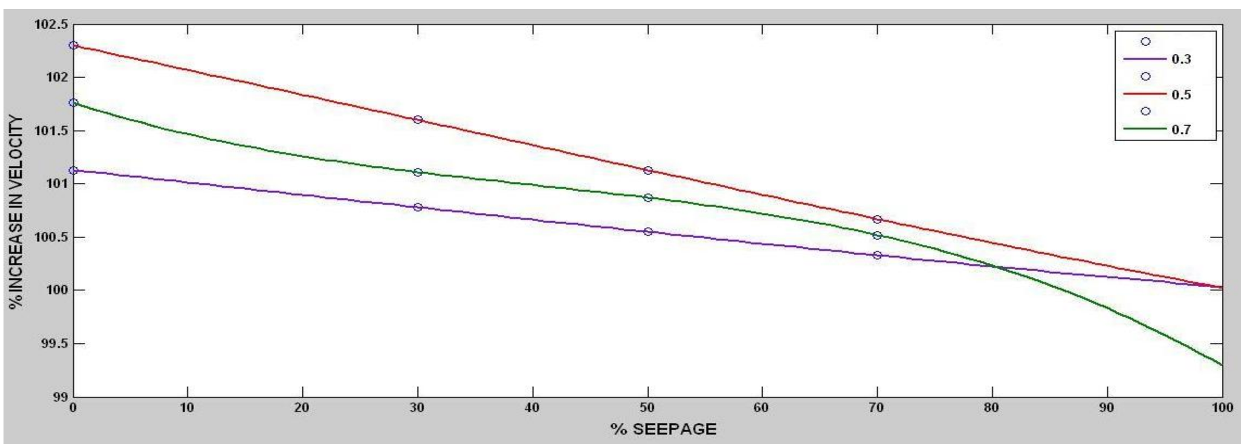


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Fig 8 , Percentage of Increase in velocity for the flaw of size ratio 1:3

3.1.3 FLAW OF SIZE RATIO 1:5

In the Fig 9, flaw size ratio 1:5 is considered for seepage analysis . The Input output ratio is considered in X axis and velocity value is taken in Y axis.

While the flaw is at the center , the domain admits less water . So the profile is at the bottom of the graph . Even with high input output ratio the variation is uniform . To analyse properly, entire record of values are normalized. The normalized graph is non linear for all the input output ratios and give the velocity as least at the center of the length of the domain. Those values are operated for the percentage of increase in velocity and it is shown by the graphical representation in Fig 10. If the Input output ratio increases the velocity of seepage also increases.

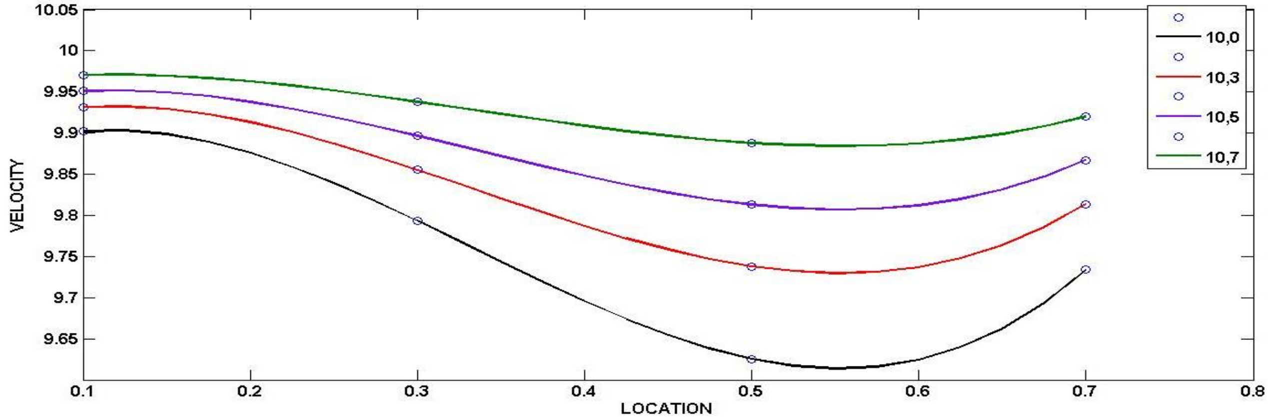

Fig 9 , Seepage analysis while the flaw of size ratio 1:5 at various location

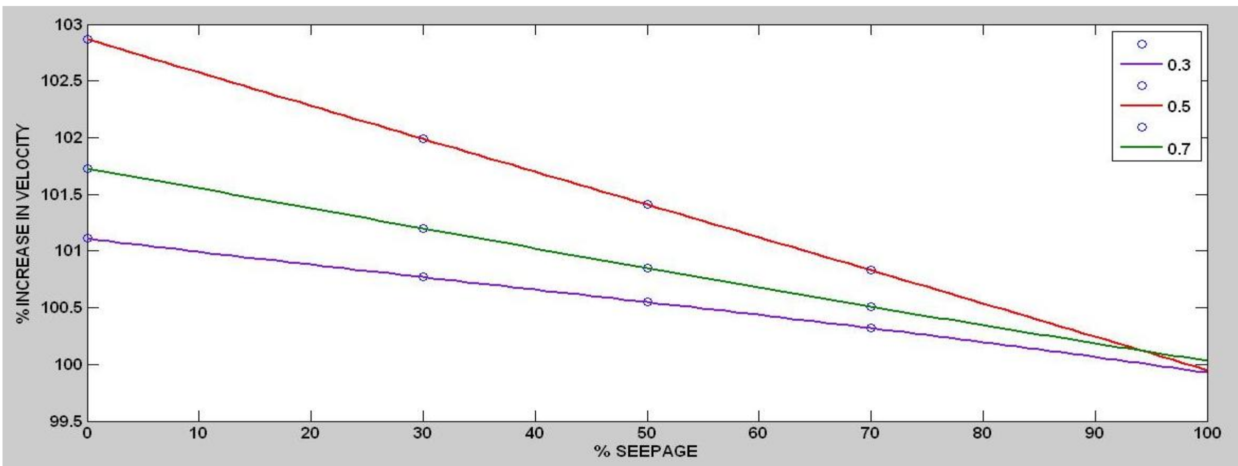

Fig 10 , Percentage Increase in velocity for the flaw of size ratio 1:5

4. ANALYSIS OF THE STRUCTURE FOR CONSTANT INPUT OUTPUT RATIO

The analysis is done for the flaws of various sizes for the selected input output ratio. If the flaw size ratio is 1:3 , the domain takes maximum velocity. Fig 25 gives the pictorial representation for the velocity of the domain with various size of the flaw under 50% output.

In the same manner Fig 12 was drawn for the selected flaw ratio of 1:3 at various locations namely 0.1L , 0.3L ,0.5L and 0.7L. 50% output was considered for the same. While the flaw is at 0.5L , velocity of seepage admitted by the domain is minimum.

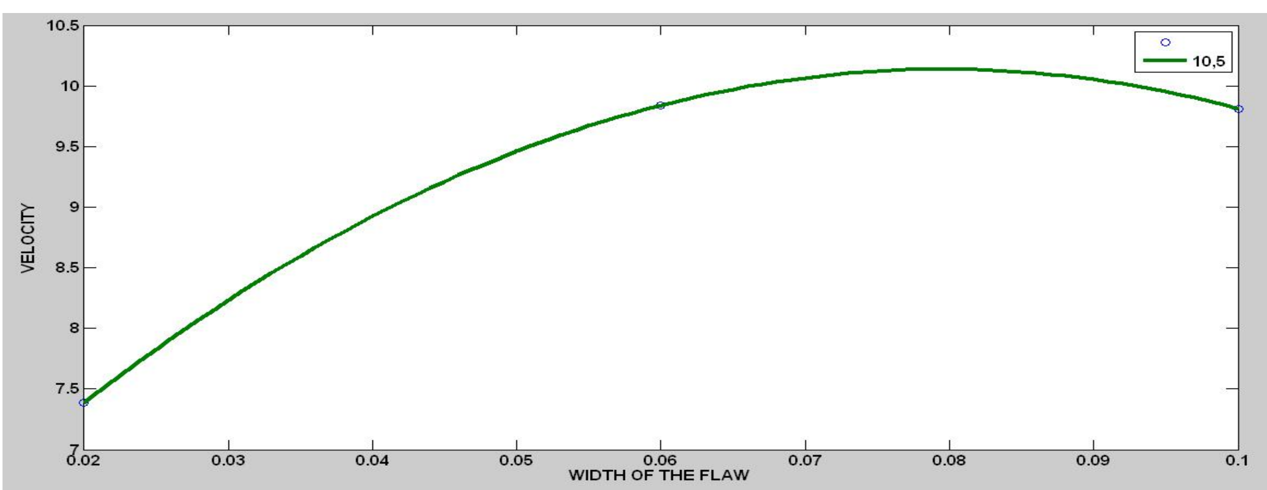

Fig 11 , Velocity curve for various size of flaw for 50% output

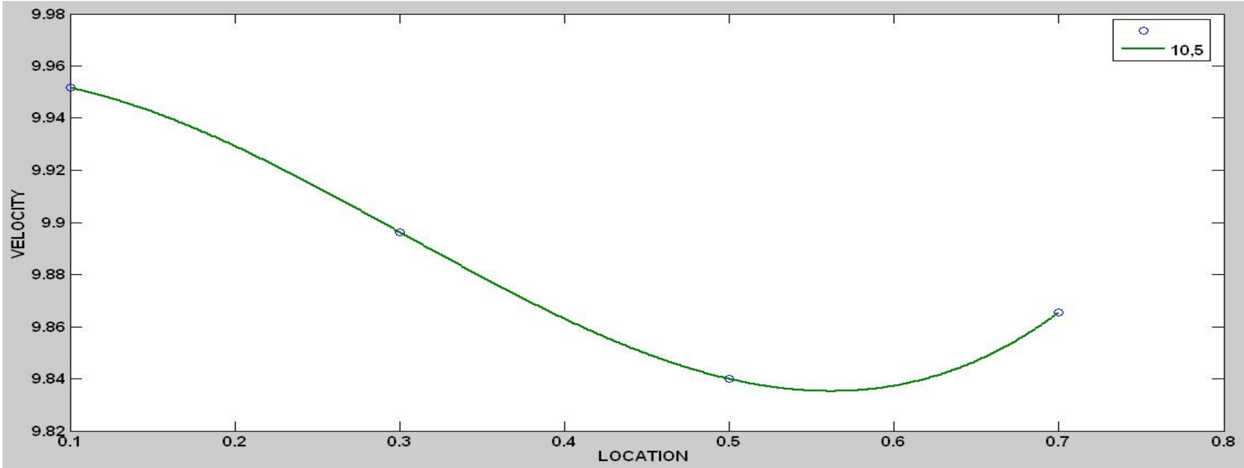

Fig 12 , Velocity curve for various location of flaw for 50% output

5. CASE STUDY OF FOR A TYPICAL DAM PROFILE

5.1 FLAW ASSUMED ON UPSTREAM SIDE TOP

The Structure ABCDEFGH is the profile of the weir chosen for the present study shown in the Fig 13. ABCDGH is the rectangular base of the structure which carries the body wall DEFG. So , the entire domain is divided as base and body wall and the study is carried out. During the analysis , water is assumed to flow through the left edge AH and exit through the right edge BC. In First phase of the study , the base of the weir is considered as a separate domain which is rectangle.

Now the flow is permitted from the top i.e., through the segment HG and the flaw is assumed at the center of the segment as shown in the figure. The width of the flaw is considered as same and the depth is varied for the study of the model. Fig 13 shows the seepage analysis curve for the domain if the flaw is assumed in the upstream side top.

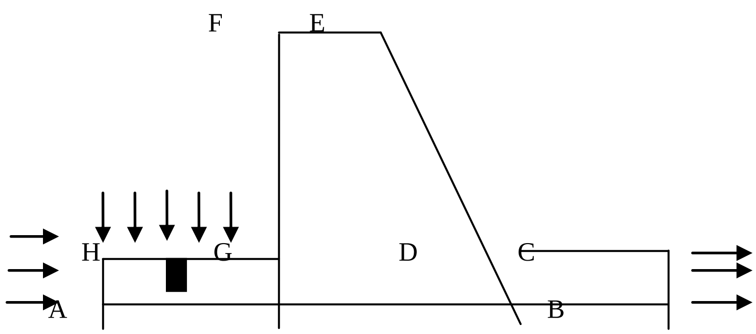

Fig 13 , Structure of the domain with the flaw in Upstream side

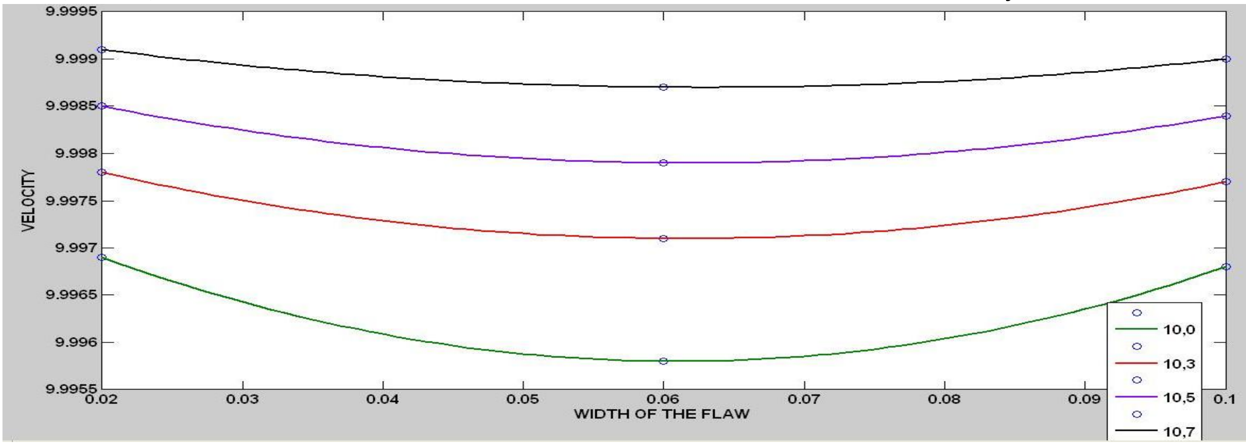

Fig 14 , Seepage analysis curve for the flaw in Upstream side

While the flaw is assumed in the upstream side boundary , Fig 14 can be drawn for various output values . It is clearly seen that the seepage profile is curvilinear and the velocity values are increasing while the output values are increased. Various output values also represents the different material of the domain and the velocity will be the factor under conductivity or permeability of the body of the domain.

5.2 FLAW ASSUMED ON DOWNSTREAM SIDE TOP

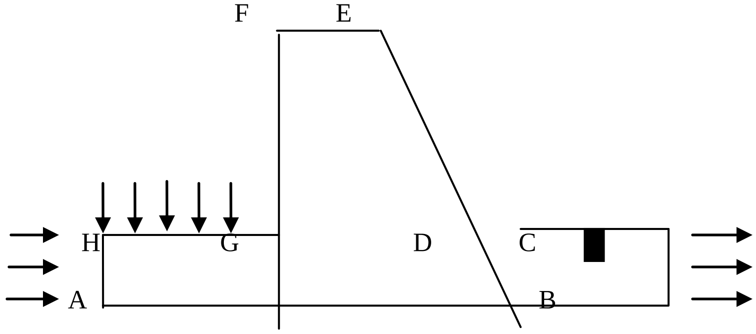

Fig 15 , Structure of the domain with the flaw in Downstream side

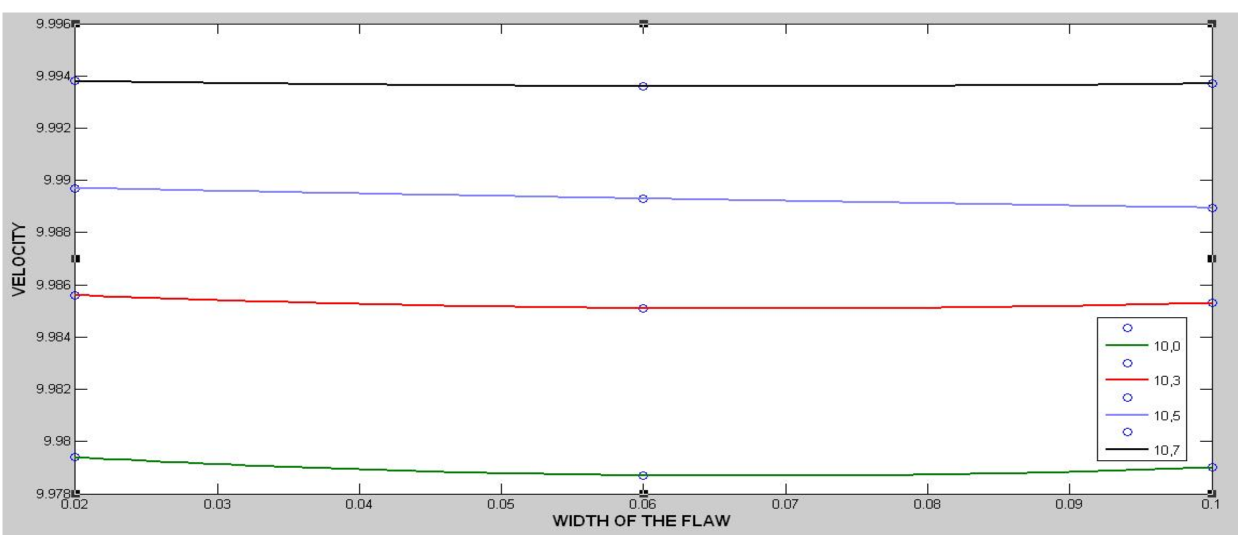

Fig 16 , Seepage analysis curve for the flaw in Downstream side

While the flaw is considered in the downstream side top , all the flaw shows the values closely equal to other. Percentage of velocity is around 99% for this case.

6. CONCLUSION

When the size of the flaw is very small , the profile at various stages are not uniform.

- While the flaw is at 0.1L and 0.3L , the variation in velocity is uniform and in increasing order.
- While the flaw is at 0.5L there is a drop in the velocity because the domain has to receive the water from same length and exit for the same length. In order to maintain entry and exit, the domain receives the seepage with low velocity.
- Irrespective of the location and size , the domain exits 99% of average velocity of seepage.
- If the flaw is assumed in Upstream and Downstream boundary at the top and if the depth is three times more than the width then the velocity decreases. If the depth is five times the width the seepage will be maximum.
- While the depth of the flaw is increases there is a small increment in the velocity taken by the flaw. In all the cases , the maximum velocity is attained by the right side top corner of the flaw .
- If the depth of the flaw increases , the normalized percentage of velocity attained by the corner of the flaw decreases.
- When the flaw is at 0.5L , the mean normalized percentage is equal.
- If the flaw is too small , the velocity variation of the domain is not uniform. So , the size ratio in which the depth is more than the width can be considered for the further study. This is only due to the least geometry of the smaller flaw.
- Since every size of flaw shows the same range of velocity and pattern of profile , can be decided that size of the flaw will not affect the flow through the domain.