Best Installation Angle for Immersion Vanes as a Measure for Meander Bank Erosion

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1-Introduction

Investigation of the flow mechanics of a river, the time changes of the river, hydraulic flow simulation and changes in the meander riverbed are some of the most important issues in the field of meandered rivers. River are subject to constant change due to erosion and sedimentation. Understanding such changes for the purpose of organizing and immunizing river against the obtained result is very important. Normally, bed erosion leads to instability of sides and this process is followed by soil mass falling and geometric deformation of the cross section of the river. The outer beach zones are displaced owing to the erosion and is a threat for riverine structures. Because of the presence of eddy flows in the meanders, the riverine erosion in the outer side and sedimentation in the inner side is much more considerable than straight paths. The erosion of the outer side leads to displacement of the arcs of the river and consequently destructs the agricultural lands, technical buildings and infrastructure and reduces the total river flood passing capacity. In order to control erosion and manage sediment in the meanders, two methods of direct protection (concrete quilt, vegetation, riprap, etc.) and indirect protection (flow pattern modifying methods) are used. Selecting the appropriate method to control erosion and sedimentation in meandering depends on environmental conditions (for instance, the implementation of concrete quilts are hampering the growth of vegetation coverage), river hydraulic conditions and economic issues.

Recently, in order to manage the sediment in meanders, direct protection methods (structural methods) are used. The first step toward ensuring that the flow pattern modifying structures can solve the problems, is design of their dimension and the placement approach, whereat these structure are able to create the required changes in the erosion and sediment patterns so that it will reach a stable limit. The immersed vane structure is one of the flow pattern modifying structures which has not been implemented yet. These vanes are similar to submerged vanes in terms of performance where the difference is that the immersed vanes are installed higher than the river bed level. The installation angle of the submerge vanes has a high importance in design since it directly affects their performance in altering the erosion and local scouring near them.

Considering the fact that the immersed vanes structure is installed higher than the river bed level, implementing them is easier and less expensive in deep rivers with constant flow compared to submerged vanes and above all, in angles with high hydrological performance, the structure is not imposed to local scouring. Moreover, there is a possibility of a higher yield in changing the bed pattern. Hence, proper installation of immersed vanes in meanders, which are not implemented yet, are investigated in this study.

2-Materials and methods:

In order to achieve to the aims of this study, a physical model of the Jangiye 180-degree arc located in the down of Ahvaz was built in the library of river models of Shahid Chamran University. The aforementioned arc has experienced different width changes during consecutive years and has caused damages to Jangiye village or nearby palm gardens. The summary of river characteristics of the site of interest is presented in Table (1).

Table. 1. River characteristics

Length of prototype section (km)	Average flow depth (m)	2-year discharge (m^3/s)	Sediment size (mm)
2	7.75	2560	0.1

According to the library condition and the present limitations and choosing the model scales of 300 and 50 respectively for horizontal and vertical dimensions, the physical model is presents in Table (2).

Table. 2. Model characteristics

Length of modeled section (m)	Average flow depth (cm)	2-year discharge (lit/s)	Sediment size (mm)
7	15. 5	2560	2

After constructing the physical model and preparing the experiment requirements, and performing each experiment for 4 hours (the time determined by primary experiments), the summary of the experiments is depicted in Table (3).

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4. Apply boundary conditions.
5. Calculate the out-of-balanced force vector.
6. If $\sqrt{\sum_{i=1}^{q}(r_i^n)^2} \le e_R$, go to (14), otherwise, continue.
7. Construct the fictitious diagonal mass matrix.
8. Form artificial damping matrix.
9. Update artificial velocity vector.
10. $\tau^{n+1} = \alpha \tau^n$
11. If $\sum_{i=1}^{q}(\dot{D}_i^{n+1/2})^2 \le e_K$, go to (14), otherwise, continue.
12. Update displacement vector.
13. Set $n = n + 1$
14. Print the result of the current increment.
15. If increments are not complete, go to (1), otherwise, stop.

To evaluate the numerical efficiency of the proposed method, some 2D and 3D truss and frame structures are analyzed with elastic linear and geometrically nonlinear behavior. For this purpose, a computer program is written based on the proposed DR algorithm, using the Fortran Power Station software. The prepared program utilizes the finite element method for modeling the structures.

The convergence of the prepared DR program is controlled by calculating kinetic energy and residual force of fictitious dynamic system at the end of each iteration.

Numerical studies prove that the proposed method is completely stable so that convergence to the static equilibrium position could be always achieved. In other words, the proposed DR algorithm guarantees the DR stability. Moreover, the convergence rate of the suggested DR process could be evaluated by comparing the number of convergence iterations. The results show that by using the proposed algorithm for fictitious mass, the convergence rate of the viscous DR method is improved so that the proposed algorithm presents the structural response with lower iterations in comparison with other common DR techniques.

4-Conclusions

By using transformed Gershgörin circles theory, which was previously used in the kinetic DR technique, a new formulation was proposed here for the fictitious mass of viscous Dynamic Relaxation method. Accordingly, a new algorithm that uses modified time step ratio was introduced for viscous DR technique. For numerical verification of the proposed algorithm, some structures such as trusses and frames with linear and nonlinear geometrical behavior were analyzed. The results could be listed as follows:

1. By performing the proposed formulation, new fictitious time step was achieved for Dynamic Relaxation method.
2. The proposed viscous DR algorithm is completely stable so that convergence to the steady state is achieved in all numerical examples.
3. The convergence rate of the proposed method is more than the well-known viscous DR techniques. In this case, a considerable reduction has occurred in required convergence iterations. In other words, the proposed technique has suitable efficiency and higher convergence rate in comparison with other common viscous Dynamic Relaxation method.
4. The proposed DR method does not impose any additional calculations to the common Dynamic Relaxation algorithm. As a result, the analysis time of the new scheme is less than the well-known DR methods.