DETERMINATION OF COMPOSITE FRICTION FACTOR AND MANNING ROUGHNESS COEFFICIENT FOR DISCHARGE ESTIMATION IN NATURAL COMPOUND CHANNELS

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Abstract

Discharge estimation is one of the major aspects in river hydraulics. For inbank flow, it is sufficient in general to calculate the discharge through a channel using one of a range of uniform flow formulas, such as the Manning and Darcy-Weisbach Equations. However, when the flow is overbank, it will become more complex due to the interactions at the interface region of main channel and flood plain. These interactions can significantly reduce the discharge capacity of a river or channel, and as a result, there is as yet no commonly accepted method for discharge estimation under overbank flow conditions.

Due to this reason, a field study has been carried out at University Malaysia Sarawak (UNIMAS), aimed at a fuller understanding of the mechanics of flow and also at evolving more accurate methods for overbank flow discharge estimation. The study involved four frequently flooded rivers with extensive data collected. These data include the geometrical data (width, depth, cross sectional shape and slope of the rivers) using a total station, and the flow measurement data (depth and velocity of the flow) using an electromagnetic flow meter. From the measurements, some 20 discharges were calculated for each of the river, covering a wide range of inbank and overbank flows. Several equations and methods have also been derived and proposed for the quantification of the interaction effects, as well as for discharge estimation, including the apparent friction factor, $f_a$; additional friction factor, $f'$; and additional roughness coefficient, $n'$. 
From the results obtained, it was found that majority of the flow during flood was carried by the main channel region, while the flood plain behaved as a storage reservoir in most cases, i.e. the mean velocity and the discharge remained near to zero (< 5%) even at very high of overbank flow, \((H-h)/H = 0.35\).

The resistance to flow in the river has been calculated in terms of Manning's coefficient, \(n\); Darcy-Weisbach friction factor, \(f\); and Colebrooke sand equivalent roughness, \(k_s\). In all cases, the results obtained show a sudden increase of resistance when the flow is just overbank due to the interaction of main channel and flood plain. Based on the methods proposed, it has been found that the interaction has resulted in a large apparent shear at the interface region of the main channel and flood plain, such apparent shear has been quantified in the forms of \(f_a\), \(f\) and \(n'\) as mentioned above. From the results obtained, it is found that the \(f_a\), which indicates the interaction activities is decrease with depth, whereas, the loss in conveyance characterized by \(f\) and \(n'\) is increased with depth. From dimensional analysis carried out, it was also found that the values of \(f_a\), \(f\) and \(n'\) are depended on the \(B/b\), \((H-h)/H\), \(M_s/M_m\), \(R_s/R_m\), \(f_{fm}\), and \(n_f/n_m\) ratios between the main channel and flood plain.

Due to the sudden increased of resistance to flow, the discharge estimated for overbank flow will be over-or-under estimated using the traditional methods. Therefore, an accurate boundary roughness needs to be estimated. It was found that the resistance for overbank flow of local natural compound channels can be estimated accurately using the equations sorted from the multiple non-linear regression analysis carried out, in terms of \(f_a\) or \(n'\).
Results obtained from discharge estimation have shown that a significant improvement has been achieved using the methods proposed (using fa or n') and equations sorted (Eqs. 9.1, 8.49, and 8.50) with a maximum error of < 12.55%, 16.64%, and 18.44%, respectively compared to those estimated using the traditional methods with maximum errors of up to 90.78%. Therefore, it has been concluded the methods proposed can be used for future discharge estimation in local natural compound channels.
Abstrak

Aliran Air Dalam Saluran Berkompaun

Anggaran Kadar aliran (discharge estimation) adalah salah satu aspek utama dalam hidraulik sungai. Bagi aliran di bawah paras tebing (inbank flow), secara amnya, ia adalah mencukupi untuk mengira aliran air melalui suatu saluran dengan menggunakan salah satu daripada formula-formula aliran uniform yang sedia ada, seperti persamaan Manning dan persamaan Darcy-Weisbach. Walau bagaimanapun, apabila aliran tersebut melepasi paras tebing (overbank flow), ia akan menjadi lebih kompleks disebabkan interaksi interaksi pada kawasan pertembungan di antara aliran pada saluran utama (main channel) dan dataran banjir. Interaksi-interaksi ini dapat mengurangkan dengan ketara keupayaan aliran bagi sesuatu sungai atau saluran, dan akibatnya, setakat ini, masih tidak ada cara yang diterima umum untuk menganggar kadar aliran pada keadaan aliran melepasi paras tebing.

Sehubungan ini, satu kajian tapak telah dijalankan di Universiti Malaysia Sarawak (UNIMAS), bertujuan untuk memahami secara medalam mengenai mekanik aliran tersebut, dan juga untuk mengembangkan kaedah-kaedah yang lebih tepat bagi anggaran kadar aliran melepasi paras tebing. Kajian ini merangkumi empat sungai yang kerap banjir, dengan data yang ekstensif telah dikumpulkan, data-data ini termasuk data geometri (lebar, dalam, bentuk keratan rentas, dan kecerunan bagi sungai-sungai tersebut) dengan menggunakan satu total station, dan data ukuran air (kedalaman dan kelajuan air) dengan menggunakan satu meter aliran electromagnet. Dari ukuran-ukuran tersebut, lebih kurang 20 kuantiti aliran melinkungi satu banjir aliran di bawah dan di atas paras tebing yang luas telah dikirakan bagi setiap sungai.
Beberapa persamaan dan kaedah juga telah dibentukkan dan dicadangkan untuk menkuantifikasikan kesan interaksi, dan juga untuk menganggar kadar aliran tersebut, ini termasuk factor geseran nyata (apparent friction factor), fa; factor geseran tambahan (additional friction factor), f; dan koefisien kekesatan tambahan (additional roughness coefficient), n'.

Dari keputusan yang diperolehi, didapati sebahagian besar aliran semasa banjir adalah dialurkan oleh kawasan saluran utama, manakala kawasan dataran banjir berfungsi sebagai satu takungan simpanan dalam kebanyakan kes, contohnya, kelajuan min dan kuantiti aliran kekal dekat kepada kosong walaupun pada paras aliran melepas tebing yang tinggi, \((H-h)/H = 0.35\).

Halangan kepada aliran air dalam sungai-sungai tersebut telah dikirakan dalam bentuk koefisien Manning, n; factor geseran Darcy-Weisbach, f; dan kekesatan setara pasir Nikuradse's, \(k_s\). Dalam semua kes, keputusan yang diperolehi menunjukkan satu kenaikan dalam halangan apabila aliran air melepas paras tebing, disebabkan interaksi di antara aliran dalam saluran utama dan dataran banjir. Berdasarkan kepada cara-cara yang dicadangkan, didapati bahawa interaksi tersebut telah menyebabkan satu ricihan nyata yang besar wujud pada kawasan pertembungan di antara saluran utama dan dataran banjir. Ricihan nyata sebegini telah dikuantitikan dalam bentuk \(fa, f,\) dan \(n'\) seperti yang disebut di atas. Daripada keputusan yang diperolehi, didapati bahawa nilai \(fa\) yang menunjukkan activiti-activiti interaksi adalah berkurangan dengan kedalaman air, manakala, kekurangan dalam penyaluran air yang dicirikan oleh \(f\) dan \(n'\) akan meningkat dengan kedalaman air. Dari analisis dimensi yang dijalankan, didapati nilai-nilai \(fa, f,\) dan \(n'\) adalah bergantung kepada nisbah-
nisbah $B/b$, $(H-h)/H$, $M_f/M_m$, $R_f/R_m$, $f_i/f_m$, dan $n_f/n_m$ diantara saluran utama dan dataran banjir.

Disebabkan peningkatan dalam halangan yang tiba-tiba, bagi aliran melebihi paras tebing, kadar aliran air yang dianggar akan berlebihan atau berkurangan jika menggunakan cara-cara tradisi. Oleh itu, satu nilai kesesatan sempadan yang jitu perlu diramalkan. Untuk ini, didapati bahawa halangan bagi aliran melepasi paras tebing untuk saluran tempatan berkompaun yang semulajadi dapat diramalkan dengan tepat, dengan menggunakan persamaan-persamaan yang diselesaikan dari analisis regresi berbilang tak linear (multiple non-linear regression analysis) yang dijalankan, dalam unsur $fa$ atau $n'$.

Keputusan diperolehi dari anggaran kadar aliran air telah menunjukkan satu kemajuan yang ketara telah dicapai dengan menggunakan cara-cara yang dicadangkan (menggunakan $fa$ dan $n'$) dan persamaan-persamaan yang diselesaikan (Persamaan 9.1, 8.49 dan 8.50) dengan kesilapan maksimum < $12.55\%$, $16.64\%$, dan $18.44\%$ masing-masing, berbanding kepada anggaran yang menggunakan cara-cara tradisi dengan kesilapan maksimum mencapai $90.78\%$. Oleh demikian, ia boleh disimpulkan bahawa cara-cara yang dicadangkan boleh digunakan untuk anggaran kadar aliran bagi saluran-saluran tempatan berkompaun yang semulajadi pada masa akan datang.
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