

FLOW CONTROL GATE ASSEMBLY

FIELD OF INVENTION

[001] This invention relates to a flow control gate assembly, in particular to a purpose-designed self-regulating water flow control gate for drainage flow improvement at merging junctions in water drainage systems.

BACKGROUND

[002] Many parts of the world are experiencing rapid urbanisation. The changes in land use associated with urban development affect drainage and flooding in many ways. Removing vegetation and soil, grading the land surface, and constructing drainage networks increase runoff to streams from rainfall. As a result, the peak discharge, volume, and frequency of floods increase in nearby streams. Changes to stream channels during urban development can limit their capacity to convey floodwater.

[003] During a storm event, this results in an increase in peak flows where more runoff is generated and flows faster into the drainage system over a shorter period of time instead of being regulated by infiltration into the soil and through evapotranspiration. This can be seen in a typical storm hydrograph showing the difference in peak runoff between an urbanised area and a pre-development, or greenfield site. The greater the degree of urbanisation, the higher the peak runoff over a shorter period of time.

[004] Urban open drainage systems are planned and built based on designated catchment areas and drained off through the main discharge channel to the river, sea or lake. With increasing urban development, the drainage system includes the formation of waterways in sections of primary and secondary sub-networks and main networks interconnected with multiple merging junctions, all of which ultimately flow to and through the main discharge channel or outlet.

[005] Typically, the catchment area, the main discharge drain outlet, as well as its discharge capacity remain unchanged over the years. However, there is a trend towards higher rainfall intensities and an increasing frequency of high intensity rain events. In addition, climate change effects of sea level rise and increases in rainfall intensities have resulted in instances where certain localities and areas experience unprecedented flooding problems. Changes made to waterway

merging flow system, i.e., when increasing multiple waterways are merged into a main discharge channel for which it was not originally designed is a significant contributing factor.

[006] Merging junctions are important elements in hydraulic networks of rivers and man-made canals. The associated flow patterns govern the transport of solutes and sediments in the network and influence the water levels of the incoming channels. Whilst we cannot manage the level of rainfall, it is possible to balance the water flow between a main flow channel and its tributaries and improve water flow rates by designing ways to streamline the flow at confluences to reduce back flow and reduce turbulence to increase the discharge rate. This allows waterways to discharge water closer to their intended flow capacities which can reduce the level and risk of flooding.

[007] Back flow of water discharge is one of the factors that contributes to flooding. Back flow is caused by restriction of discharge at certain sections of flow due to hydraulic or physical elements. The various physical elements include the size ratio, shape, slope/elevation or angle between the two merging channels while the hydraulic elements include the nature of the downstream flow, and the two upstream merging flow rate ratio.

[008] Back flow on its own does not automatically result in flooding if the upstream channel system is able to accommodate the additional backflow during the peak flow rate. Flash flood happens during peak flow where discharge rate is lowered due to energy loss and energy transfer. Back flow is energy transfer and store to upstream higher elevation.

OBJECTIVE

[009] It is an object of the invention to provide a flow control gate for installation close to or at merging junctions of open drainage systems to improve the water flow pattern at the confluence, which typically comprises a mixing layer; shear layer; separation zone; and stagnation zone which develop, narrowing the flow opening downstream of the merging junction and result in flow restriction and back flow.

[0010] The separation zone is an internal recirculation flow with high turbulence and lower water level just downstream of the merging junction, resulting from a contracted discharge section of higher velocity. The stagnation zone is formed at the upstream merging point. It is the start where the upstream flow merges, the stagnation effect arises due to balance of merging flows hydraulics.

The mixing layer is a turbulent flow belt form by unsteady flow hydraulics of the merging flows, it starts from stagnation zone and end at downstream with lamina flow.

[0011] All three features, the stagnation zone, separation zone and mixing layer potentially induce back flow by restricting the effective flow opening. Internal circulation or turbulence is energy loss in water flow momentum and back flow is an unwanted form of energy transfer back to the flow source.

[0012] Mechanical flow control gates may be used to improve the discharge flow rate to minimize the back flow and consequently the flash flood effect to the affected drainage system outlet. The flow control gate design may exist in multiple forms, its design being dependant on the variation of the merging junction and its potential flow. The primary function of the flow control gate is to reduce or minimise the back flow due to hydraulic formation or physical elements at peak flow.

[0013] The efficacious design of the flow control gate provides automatic water flow improvements by preventing or reducing the formation of turbulent water flow at merging drain junctions and streamlining water flow without making major changes to existing drain structures. Improvement to the flow pattern at the merging junction ultimately results in an increase of the water flow rate and allows a drainage system to discharge more water.

[0014] The increased discharge flow rate and streamlined water flow at the merging junction alleviates the problem of backflow, thereby resulting in avoidance or reduction of upstream overflow at locations that are unable to accommodate the additional backflow during the peak flow rate and minimising the flood risk in such areas.

[0015] Such automatic flow control gate is self-adjusting and may swing automatically into the best and most optimal position required to balance the inertial forces from each of the merging flow, thus reducing backflow. A basic automatic flow control gate can be in the form of a single rigid gate mounted to a fixed wall or fixed pole angularly rotatable about a vertical axis. Based on historic discharge values of the merging junction, for merging junctions where the discharge rate of the tributary is low, additional features may be provided to the automatic flow control gate to further increase the discharge rate of tributary.

[0016] The free-swinging end of the automatic flow control gate may be extended with a flexible vane to further improve the streamlining of water flow and reduce the influence and impact of the mixing layer flow pattern. Additionally, a minor diversion window may be added to divert a fraction of the upstream flow to merge with the tributary discharge before the combined stream acts on the automatic flow control gate. The bleeding of water from the higher pressure to lower pressure flow side of gate initiates and support the gate to swing open to allow higher tributary discharge rate at the balanced position.

[0017] When both the merging channel openings are substantially large and the flow current inertial forces are strong, a complex automatic flow control gate with multiple panels interconnected by flexible member arranged with bleeding windows may be suitable. The complex automatic flow control gate may be constructed from multiple rigid panels arranged horizontally to form a series of panels with flexible interconnections to extend the gate width. Multiple rows of the series of panels may be arranged vertically independent to each other, or interconnected with flexible material, in the form of a 3D-flexible arrangement of interconnected flexible panels, capable of flexing in 3D to diffuse the forces and direct the water discharge to its best and most optimal flow pattern. Such designs are suited for complex dynamic forces at different levels of water depth.

[0018] As the automatic flow control gate is relatively substantial in size, the automatic flow control gate may be arranged to be activated only at predetermined water levels. A float fixture can be added as a control switch to activate the flow control gate when the water level reaches a predetermined level where turbulent water flow pattern occurs the merging junction. The float fixture further performs an auto-closing function to lock the flow control gate in an inactive position once the water drops below the predetermined level.

BRIEF DESCRIPTION OF DRAWINGS

[0019] FIG 1: Typical hydraulic flow pattern at an open drainage merging junction

[0020] FIG 2: Improved hydraulic flow pattern at an open drainage merging junction with automatic flow control gates installed

[0021] FIGs 3A & 3B: Planar automatic flow control gate installed in two ways at a merging junction

[0022] FIGs 4A & 4B: Curved automatic flow control gate with flexing trailing member installed in two ways at a merging junction

[0023] FIGs 5A & 5B: Complex automatic flow control gate with flexing trailing member and bleeding window installed at a merging junction

[0024] FIGs 6A and 6B: Complex automatic flow control gate with interconnected panels and details of the auto-activation mechanism

DETAILED DESCRIPTION

[0025] The general flow features of an open drainage merging junction is illustrated in FIG 1. At the point where the two incoming flows meet, a stagnation zone develops, i.e., a zone of reduced flow velocity. From the stagnation zone, a mixing layer departs, which delineates the merging streams. At the downstream junction corner, the tributary flow may detach, causing the formation of a separation zone. Next to the separation zone, the merging flows passes through a narrowed cross-section, forcing the merging streams to flow at increased velocities.

[0026] FIG 2 illustrates the improvement in flow characteristic of the same open drainage merging junction after two automatic flow control gates have been installed. The presence of the stagnation zone, mixing layer and separation zone is reduced, resulting in a more streamlined flow pattern. The automatic flow control gates **200** have a curved profile and are pivotally mounted on fixed poles erected from the floor of the drain. Both automatic flow control gates **200** have a flexible trailing vane **240** to further improve the streamlining of water flow. The positioning of automatic flow control gates **200** with respect to the merging junction is determined by historic discharge values of the merging junction and may be adjusted to maintain optimal performance if such discharge values changes significantly. The placement of the two gates is specially positioned to remove the potential formation of the stagnation zone, by resolving the formation of turbulence flow of the mixing layer and minimise the helicoidal recirculation in the separation zone. Through minimising the merging flow interference, the placement of the gates results in improvement in the flow of water, for a variety of flow input ratio at all times.

[0027] FIGs 3A & 3B are schematic sectional views of a first embodiment of automatic flow control gate **100** according to the invention. Rainwater drains from a tributary to a major drain that is also carrying rainwater downstream. The tributary merges with the major drain at 90 degrees but the invention applies to drainage systems for other junction angles. Automatic flow control gate **100** is a rigid planar barrier gate preferably constructed in steel but may be constructed from other materials such as engineering polymers. Automatic flow control gate **100** is generally rectangular in shape but may also include curved, irregular or rounded edges. Height h_g of automatic flow control gate **100** may be less or equivalent to the depth of the tributary. The automatic flow control gate **100** extends into the flow channel between the major drain and the tributary. The width of automatic flow

control gate **100** W_g is less than the width of the discharge opening of the tributary W_t so that automatic flow control gate **100** does not completely block the discharge of the tributary when ratio of upstream discharge to tributary discharge q is very high. Preferably the W_g/W_t is between 0.33 to 0.5. Automatic flow control gate **100** is smaller than the tributary in height and width to prevent full closure of the tributary in any situation.

[0028] As seen in FIGs 3A and 3B, a first end of automatic flow control gate **100** is rotatably connected to anchor mountings **40** affixed to the inner walls of the tributary and main drain by hinges or flexible member for rotation about its vertical edge. In FIG 3A, automatic flow control gate **100** swings freely in a horizontal orbit along a vertical axis defined by its connected first end in the flow channel. The angle of swing of automatic flow control gate **100** may be mechanically restricted to a range less than its maximum range as defined by the inner walls of the tributary and main drain. In FIG 3B, automatic flow control gate **100** is connected to anchor mountings **140** by a flexible member **120** for both swinging and translation motion.

[0029] When rainwater rushes through the upstream drain and tributary, inertial forces due to the momentum of the rainwater from upstream and the tributary are exerted on opposing sides of automatic flow control gate **100** and automatic flow control gate **100** swings dynamically into an optimal position that balances the inertial forces from the merging streams.

[0030] In another preferred embodiment as shown in FIGs 4A and 4B, automatic flow control gate **200** is a rigid panel with a curved cross-sectional profile. Automatic flow control gate **200** is suitable for installation in merging junctions when the discharge of the tributary Q_t is low relative to the upstream discharge of the major drain Q_u , i.e. where $0.8 \leq q$. When installed, the concave side of automatic flow control gate **200** is typically arranged to face the opening of the tributary. In heavy storm conditions, rainwater rushes through the major drain and tributary. Inertial forces due to the momentum of the rainwater from the main drain and tributary are exerted on opposing sides of automatic flow control gate **200** and automatic flow control gate **200** swings dynamically into an optimal position that balances the inertial forces from the merging streams. The cross-sectional profile of automatic flow control gate **200** results in automatic flow control gate **200** swinging further into the upstream channel as compared to automatic flow control gate **100** of same dimensions under the same flow conditions, thus allowing higher discharge rate of the tributary stream into the major drain.

[0031] The curved profile of automatic flow control gate **200** further improves water flow from upstream and the tributary before merging. The presence of automatic flow control gate **200** at the merging junction reduces and interrupts the formation of the stagnation zone at the leading end of the merging junction corner and cuts down the turbulence effect from the mixing layer as the merging flows are physically divided by the gate. It also reduces the circulation effects at the separation zone caused by the mixing layer. These improvements effectively increase the flow rate due to the increase of the effective channel opening and reduction of the turbulence flow. The extended flexible trailing vane **240** connected to the end further streamlines the merging flow.

[0032] Flexible trailing vane **240** flexes in response to the difference in inertial forces between Q_u and Q_t to further improve the streamlining of water flow and reduce the influence and impact of the mixing layer flow pattern on the stability of automatic flow control gate **200** at its dynamic equilibrium position. Similarly, the effective width of rigid gate **200** is less than the width of the tributary W_t so that gate **200** will not completely block the discharge of the tributary when discharge ratio q is very high.

[0033] Automatic flow control gate **200** may be installed at a drainage merging junction by connection to anchor mountings **40** in the same two manner as described in the first embodiment of the invention. Alternatively, automatic flow control gate **100**, automatic flow control gate **200** and subsequent embodiments of the invention may be installed at a merging junction by connecting to axial supports **80** fixed to the floor of the drain as shown in FIG 2. The axial support **80** is generally vertical and in a spaced arrangement from the inside corner of the merging junction. In addition, more than one automatic flow gates **100**, **200** may be installed at a drainage merging junction, as illustrated in FIG 2.

[0034] A third preferred embodiment is shown in FIGs 5A and 5B, for use in merging junctions where the discharge of the tributary Q_t is low in relation to the upstream discharge of the major drain Q_u , i.e. $0.8 \leq q$. Automatic flow control gate **300** is connected to anchor mountings **40** by a flexible member **320** for both swinging and translation motion. A C-shape cut is made in flexible member **320** to form a bleeding window **350** to divert a portion of the upstream discharge before it reaches flow control gate **300**. The diverted stream is directed such that its flow impinges against the tributary-facing side of automatic flow control gate **300**. The combined diverted upstream discharge and the discharge of the tributary forces automatic flow control gate **300** to swing further towards the main drain, as compared to flow control gate **100** of same dimensions under the same flow conditions. Alternatively, bleeding window **350** may be in the form of a hinged vane rotatable along

a vertical axis and configured for flow of fluid in only one direction, so that a portion of the upstream flow joins the tributary discharge before automatic flow control gate **300** and not vice versa. The cross-sectional profile of bleeding window **350** may be curved to direct the diverted flow of upstream discharge to impinge on the tributary-facing side of automatic flow control gate **300**. Bleeding window **350** may be fully rigid or flexible. Automatic flow control gate **300** may additionally include a flexible trailing vane **340** that extends from the free-swinging end of the gate.

[0035] In yet another embodiment of the invention as shown in Fig 6A, a complex automatic flow control gate **400** with automatic activation at a designated level of water in channel by a float assembly **410** is disclosed. Complex automatic flow control gate **400** is framed by a rigid right-angled arm **405** made of steel, the vertical section of arm **405** having a first end that is telescopically received and rotatable along a horizontal plane on an axial support **80** fixed to the floor of the main drain. A rectangular float assembly **410** is housed between the horizontal section of arm **405** and the uppermost portion of the vertical section of the arm **405**. The float assembly **410** may be made of a light weight housing filled with buoyancy material or air.

[0036] During installation, complex automatic flow control gate **400** is set in a spaced arrangement from the inside corner of the merging junction. A minor bleeding window gate **450** is provided between the axial support and the inside corner of the merging junction to divert a portion of the upstream discharge before it reaches complex automatic flow control gate **400**.

[0037] An array of rigid panels **425** interconnected by flexible membrane **430** extends below float assembly **410**. A first section consists of right-angled triangular rigid panels **425** arranged into a rectangular grid, the panels separated from one another by a narrow gap of the flexible membrane **430**. Between the mounted vertical arm of complex automatic flow control gate **400** and the grid of triangular rigid panels **425**, a number of rectangular rigid panels **425** arranged vertically and separated from one another by a narrow gap of the flexible membrane are disposed. Another rigid rectangular panel **425** is disposed between the horizontal section of the arm and the grid of triangular panels. The above-mentioned rectangular panels **425** are similarly separated by adjacent panels by a narrow gap of flexible membrane **430**. The panels may be made of metal such as aluminium or engineering polymers. These gaps of flexible membrane create channels of preferred flexing across this section of complex automatic flow control gate **400**. Flexible vanes **440** extend from the free-swinging ends of the complex arrangement of rigid panels and may be constructed from nylon sheet. More rigid panels **425** can be used to produce additional channels of flexing.

[0038] Wires **435** extending from the horizontal section of arm **405** connects to a number of the rigid panels **425** to directly support the weight of such panels. As illustrated in the FIG 6A, these wires **435** extend vertically downwards in spaced arranged disposed along the length of the horizontal arm. A first wire is connected to the vertical row of rectangular rigid panels **425** and next two wires are each connected to vertically aligned triangular rigid panels **425**. These wires can also be replaced with a single common wire. This setting changes will reduce the flexibility of the complete gate.

[0039] The automatic activation mechanism of complex automatic flow control gate **400** is more clearly shown in FIG 6B. A vertical slot **85** is located at the base of axial support **80**. Slot **85** receives pin **415** which is located towards the first end of arm **405** and extends transversely from the arm. Slot **85** prevents arm **405** from rotation about the horizontal plane.

[0040] During dry weather or limited rain, complex automatic flow control gate **400** is in an inactive state. In the inactive state, complex automatic flow control gate **400** is locked from rotation and its free swinging end turned towards upstream direction of the major drain, minimally affecting the upstream flow of the major drain. During heavy rain, rainwater fills the major drain and tributary. At a predetermined depth of rainwater in the drains, complex automatic flow control gate **400** begins to float. Arm **405** rises telescopically from axial support **80**, guided by slot **85**. No rotation of arm **405** and consequently no rotation of complex automatic flow control gate **400** is possible at this stage. At a predetermined height, pin **415** exits slot **85** and is guided by the exposed end of axial support **80** to turn in a predetermined direction while continuing to rise. At a final predetermined height at which complex automatic flow control gate **400** floats, gate **400** is in the active state and freely rotates about in the horizontal plane. Inertial forces due to the momentum of the rainwater from the main drain and tributary are exerted on opposing sides of gate **400** and gate **400** swings dynamically and flexes along the various channels of flexing across the arrangement of rigid panels **425** into an optimal position that balances the inertial forces from the merging streams.

[0041] When the water level in the drains drop, gate **400** descends and swivels along the exposed end of axial support **80** until pin **415** engages with slot **85**, returning gate **400** back to the inactive state.

[0042] There may be instances where more than one automatic flow control gates are installed at a merging junction. As shown in FIG 2, two flow control gates **200** which are rigid with a curved cross-sectional profile, each extended with a flexible vane **240** are installed on axial supports **80** fixed to the floor of the main drain at a merging junction. Multiple simple gates arrangement according to the first and second embodiments is always a preferred option as compared to installation of a complex gate according to the third and fourth embodiments as multiple simple gates are effective in overcoming multiple physical structure imperfections in the merging junction such as channel wall misalignment or other nearby structures such as column from building column or bridges.

[0043] From the foregoing disclosure and detailed description of certain preferred embodiments, it is also apparent that various modifications, additions and other alternative embodiments are possible without departing from the true scope and spirit of the present invention. For example, the bleeding window may be substituted by unidirectional slits, similar to grater slots/slits in the gate to divert a portion of the upstream flow to join the tributary discharge. The embodiments discussed were chosen and described to provide the best illustration of the principles of the present invention and its practical application to thereby enable one of ordinary skill in the art to utilize the invention in various embodiments and with various modifications as are suited to the particular use contemplated. All such modifications and variations are within the scope of the present invention as determined by the appended claims when interpreted in accordance with the benefit to which they are fairly, legally, and equitably entitled.

CLAIMS

1. An automatic flow control gate for installation close to or at a merging junction of an open drainage system, the drainage system having a major drain and a tributary that merges with the major drain at the merging junction, the major drain and tributary each having a bottom wall and side walls to define the passage of water flow, the discharge of fluid from the major drain and tributary forming a stagnation zone from the upstream merging point of the merging junction, the gate comprising:
 - a first end securable to and rotatable in a horizontal orbit about a support;
 - a second free-swinging end extending at least partially into the merging junction;
 - a first side; and
 - an opposing side;whereby said automatic flow control gate swings dynamically in response to upstream discharge of the major drain impinging on its first side and tributary discharge impinging on its opposing side into an optimal position that balances the inertial forces from the merging upstream discharge and tributary discharge, and the height and width of the gate is less than the depth and width of the tributary to prevent full closure of the tributary in any situation.
2. An automatic flow control gate according to claim 1 whereby the gate is rigid.
3. An automatic flow control gate according to claim 1 or 2 whereby the gate is planar.
4. An automatic flow control gate according to claim 1 or 2 whereby the gate has a curved profile.
5. An automatic flow control gate according to claim 1 whereby the gate is capable of flexing.
6. An automatic flow control gate according to claim 5, whereby the gate is formed from an array of rigid members interconnected by flexible membrane.

7. An automatic flow control gate according to claim 5, whereby the gate comprises a vertical series of unconnected rows of rigid members, the rigid members interconnected by flexible membrane.
8. An automatic flow control gate according to any one of claims 1-7, whereby rotation of the gate is about a fixed pivot.
9. An automatic flow control gate according to any one of claims 1-7, whereby rotation of the gate is through bending of a flexible member connected to the support.
10. An automatic flow control gate according to any one of claims 1-9, further comprising a flexing trailing member extending from said free-swinging end.
11. An automatic flow control gate according to any one of claims 1-10, further comprising at least a fluid diverting means to divert a portion of the upstream discharge of the major drain to combine with the tributary discharge.
12. An automatic flow control gate according to claim 11, whereby the fluid diverting means is one or more bleeding windows.
13. An automatic flow control gate according to claim 12, whereby the bleeding window has a curved profile to direct the diverted upstream discharge to impinge on tributary facing side of the gate.
14. An automatic flow control gate according to claim 9, whereby one or more bleeding windows are formed by cuts in the connecting flexible member.
15. An automatic flow control gate according to claim 11, whereby the fluid diverting means are unidirectional slits in the gate.
16. An automatic flow control gate according to any one of claims 1-15 further comprising an automatic activation mechanism.

17. An automatic flow control gate according to claim 16, whereby the automatic activation mechanism is activated at a pre-determined water level in the merging junction.
18. An automatic flow control gate according to claims 15 or 16, whereby the automatic activation mechanism comprises a swivel lock and float assembly.
19. An automatic flow control gate according to any of claims 1-18 whereby the support is where the side wall of the major drain first meets the side wall of the tributary.
20. An automatic flow control gate according to any of claims 1-18 whereby the support is an axial support extending vertically from the bottom wall of the merging junction.
21. The method of drainage flow improvement at a merging junction in water drainage systems by installing one or more automatic flow control gates according to any of claims 1-20 close to or at the merging junction.
22. The method of claim 21, whereby the one or more automatic flow control gates are installed at the stagnation zone of the merging junction, such that the formation of such stagnation zone is reduced.