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Effects of Neighboring Building on Wind Loads

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Abstract

The evaluation of wind loads on buildings in Korea is carried out mainly by using Korean Standard Design Loads for Buildings, whose specifications are generally based on wind-tunnel tests performed on isolated structures considering wind exposure. However, it has been shown that wind loads on buildings in realistic environments surrounded by neighboring buildings may be considerably different from those measured on isolated buildings. Wind-induced interference effects may depend mainly on the geometry and arrangement of these structures, their orientation and upstream terrain conditions. The most important factor among them is the arrangement of building structures, which can directly change the flow. It is examined in this study that how wind loads on a high-rise building with square section are affected by the arrangement of neighboring buildings with side ratios of 1.0-2.5 to the measured building. The study of wind-induced interference effects on high-rise buildings was performed by wind-tunnel tests of force balance model. Interference factor was defined as ratio of wind force on a building with interfering buildings present to wind force on an isolated building.

Keywords: Interference; Wind-induced force; wind-tunnel; wind loads; high-rise buildings

1. Introduction

The evaluation of wind loads on buildings in Korea is carried out by using Korean Standard Design Loads for Buildings, wind tunnel tests, and CFD(computational fluid dynamics) techniques. It is normal to use standards and codes in the initial design stage. The specifications in the standard are based on wind-tunnel tests performed on isolated structures. However it has been shown that wind loads on buildings in realistic environment may be considerably different from those measured on isolated buildings.

Wind-induced interference effects on buildings are not a recent research topic. The earliest work related to interference effects dates back in the thirties. Harris found that torque on the Empire State building in New York would be doubled if two building blocks were built across the two streets adjacent to the building. Bailey and Vincent attempted to determine general relationships between wind-speed and the distribution of wind-pressure over sloped, flat and stepped roofed buildings, both under fully exposed conditions and when in close proximity to other buildings. A lot of studies on interference effects have been studied since the collapse of three out of the eight natural draft cooling towers at Ferrybridge, England [3],[4].[5],[6],[7],[8],[9],[10],[11],[12]. The studies include shielding effects of upstream buildings, aerodynamic interference due to tall buildings, interference effects due to groups of buildings and flow visualization studies to explain the phenomenon of interference [13].

Although many works have been done, there are very few of a comprehensive and generalized set of guidelines for wind load modifications caused by adjacent buildings. Three main reasons appear to explain the lack of the guidelines. First, the complex nature of the problem even for a single additional building; second, the scarcity of adequate experimental data; and third, the widely held notion that wind loads on a building are expected to be generally less severe if surrounded by other structures than when it is isolated. This last reason becomes debatable where only two or three

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buildings interact, since several studies have shown quite adverse effects depending on the relative location of these buildings.

There are many parameters which cause wind-induced interference effects. These are size and shape of the building, wind velocity and direction, type of approach terrain and above all, the location of proximity of neighboring buildings. The most important one among these parameters may be the arrangement of building structures which can change the air flow directly. It is examined in this study that how wind loads on a high-rise building with square section are affected by the arrangement of neighboring buildings with side ratios of 1.0-2.5 to the measured building. The study of wind-induced interference was performed by wind-tunnel tests of force balance model.

2. Experimental Set-Up

Force balance wind-tunnel tests were performed for the investigation of wind-induced interference effects. The wind-tunnel tests were conducted in the boundary layer wind tunnel of Hyundae Institute of Construction Technology (4.5m wide, 2.5m high, 25m long) (see Fig. 1).

The wind tunnel model is a 1/200 scale-down model with square section, aspect ratio of 6. Neighboring buildings with side ratios of 1.0-2.5 to the measured building are arranged up to the 4B in acrosswind direction and 10B in alongwind direction (B is the width of the measured building). The definition of separation is distance between the centers of the measured building and the neighboring building.

The wind flow was simulated in the tunnel, standing for the wind blowing in the suburban or forests. Fig. 3 shows the mean wind velocity and turbulence profiles. The power-law index is 0.22. To investigate the effect of the arrangement of the neighboring building, the arrangement plan was prepared as shown in Figs. 4 and 5. The size of the grid is equal to the width of the measured building. The neighboring building is positioned by 1B to the spanwise and alongwind directions. For the alongwind wind forces,

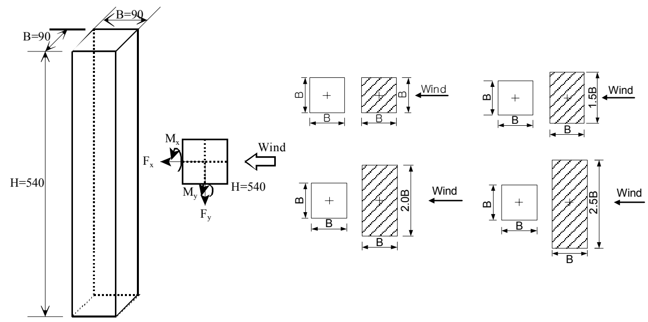

Fig. 2. A measured building and neighboring buildings

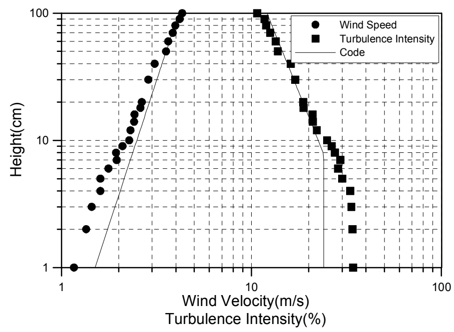

Fig. 3. Mean wind velocity and turbulence profiles

the mean and the fluctuating values were taken into account in the wind-induced interference factor.

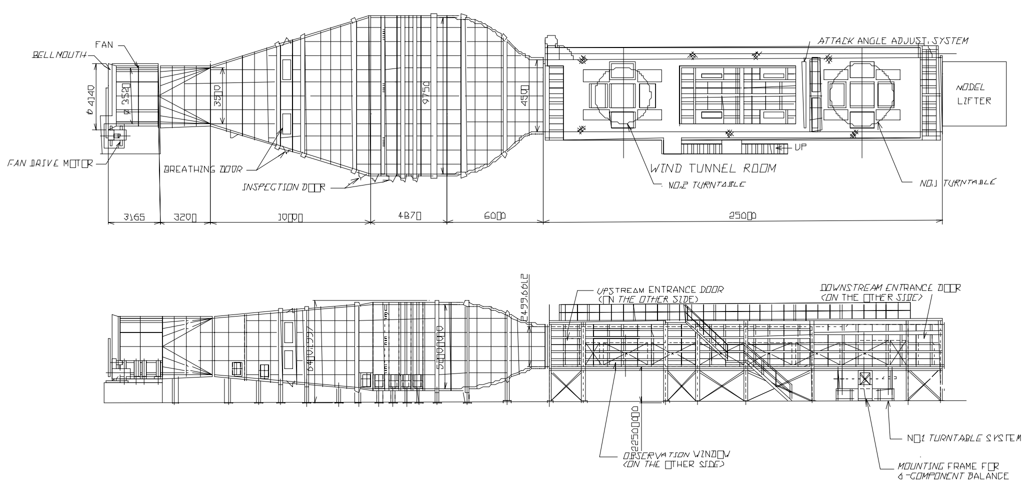

Fig. 1. Boundary layer wind tunnel

However, for the acrosswind and torsional directions, only fluctuating wind forces were considered.

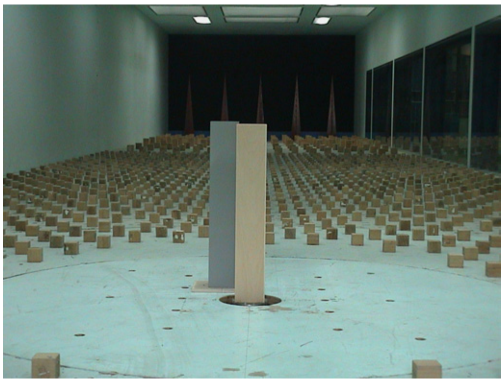

Fig. 4. A view of relative building arrangement in the wind tunnel

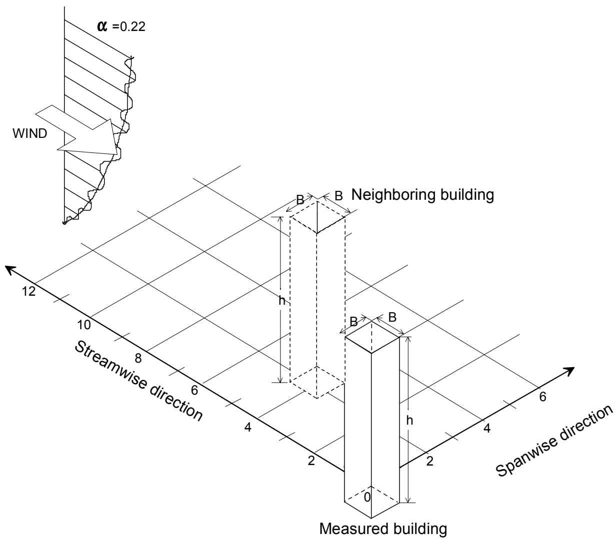

Fig. 5. Building arrangement plan and grid

3. Experimental Results

Interference factor was defined as ratio of wind force on a building with interfering buildings present to wind force on an isolated building. The vertical axis is alongwind separation and the horizontal axis is spanwise separation. Neighboring buildings either decreased or increased the flow-induced forces on a building. If the interference factor (IF) is greater than 1, the wind force of the measured building is increased by the neighboring building. If the IF is smaller than 1, the wind force is decreased by the shielding effect of the upstream building.

Fig. 6 shows interference factors of alongwind mean wind force with side ratio of the neighboring buildings. When Y=0, the shielding effect is dominant. When the neighboring building is very close to the measured building, even the negative force was generated. When X is small and Y becomes larger, the interference factor goes up to 1.2. This means that the wind load was increased by 20% those on an isolated building. The separated flow in the upstream building was accelerated and directly approached to the façade, and consequently the alongwind mean force was increased.

Fig. 7 shows the interference factors of alongwind fluctuating wind force. When the neighboring building is parallel with the measured building in the alongwind direction, the interference factor is in the range of 0.4~0.6 and then is increasing with the separation and is stabilized. The stabilized value is I the range of 0.7~0.8. This explains that when the measured building is isolated, the fluctuating component of the approach wind is working on the windward side and simultaneously the fluctuating suction force is working in the leeward side while turbulent flow generated in the downstream neighboring building may interfere with the well-organized vortex-shedding formation in the measured building.

Fig. 8 shows the interference factors of acrosswind fluctuating wind force. When the measured building was submerged in the wake of the neighboring building (Y=0), the acrosswind force of the measured building can be generated not by the flow separation of the measured building but by the flow separation of the upstream neighboring building. When Y=0 and X=10.5, the interference factors converged to 0.7~0.8, still less than 1.0. This is because the turbulent flow in the wake of the upstream neighboring building interferes with the generation of well-organized vortex on the corner of the measured building.

Fig. 9 shows the interference factors of fluctuating torsional moment. When the neighboring building is very close to the measured building in the alongwind direction, the shielding effect is dominant but the interference factor is increasing with separation. This is because the alternating vortex in the upstream neighboring building is working on the measured building alternately. The fluctuating torsional moment increased 40% that of the isolated building when Y=1~2B and the neighboring building is very close to the measured building in the alongwind direction.

4. Conclusions

The wind-induced interference on building load was affected mainly by the geometry and arrangement of these structures, their orientation and upstream terrain conditions. This study was focused on the building arrangement of the neighboring building. The wind-induced interference was studied with variation of side ratio of the neighboring building. The 4 different side ratio was in the range of 1:1~1:2.5 with increment of 0.5B.

The wind-induced interference effect is very complex problem. The neighboring building may increase or decrease wind loads, depending on the relative location to the measured building. For the alongwind mean force, the shielding effect was dominant but in a certain arrangement the adverse effect increased the wind loads up to 10%~20%. For the acrosswind direction, in a certain arrangement the acrosswind wind load increased up to 30% that of the isolated building. Torsional moment also can increase up to 40%.

The wind-induced interference effect was mainly dependent on the shielding area, wake region, and the vortex street of the neighboring building. It seems that visualization study is essential to the interference study. Authors believe that the interference factors under the given condition may be quite helpful to the structural designers in the initial design stage.

Acknowledgement

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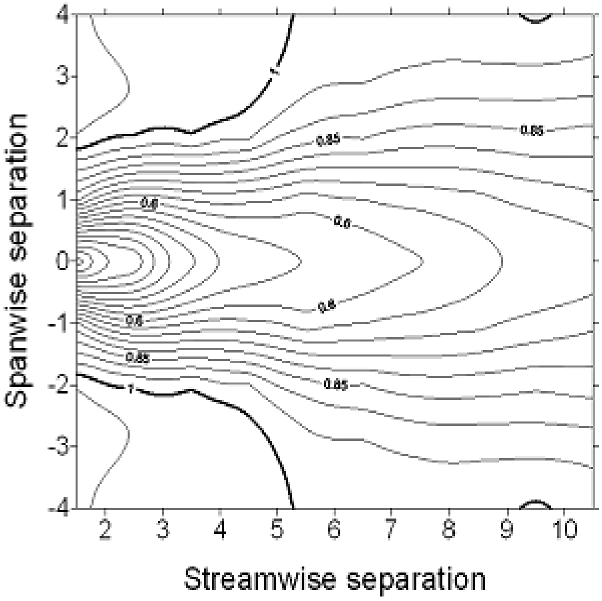

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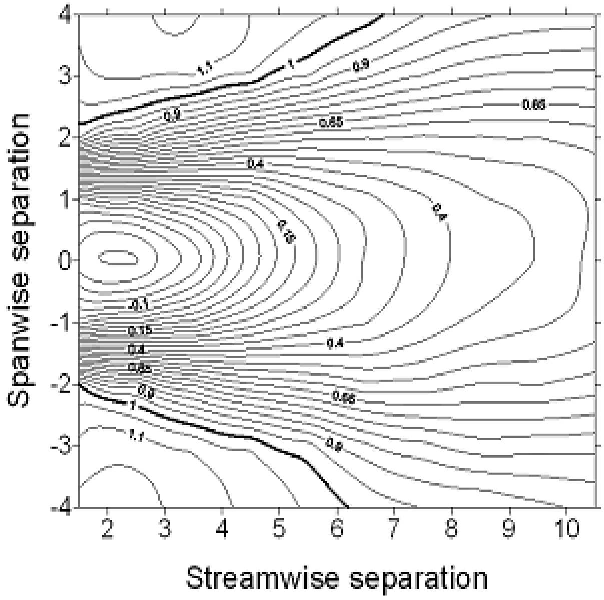

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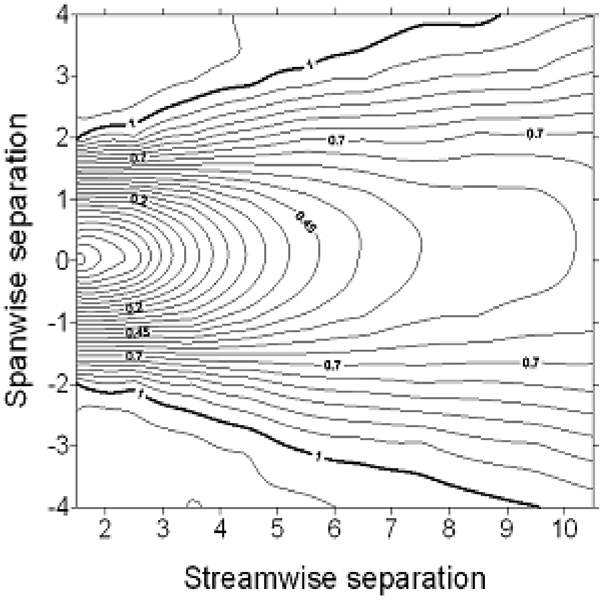

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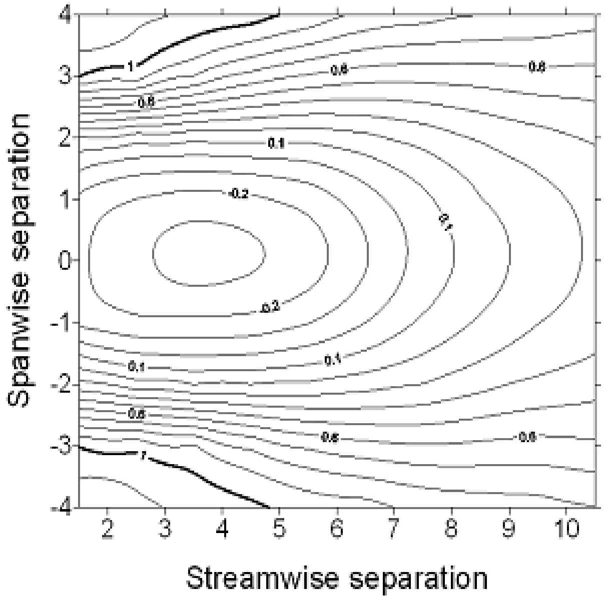

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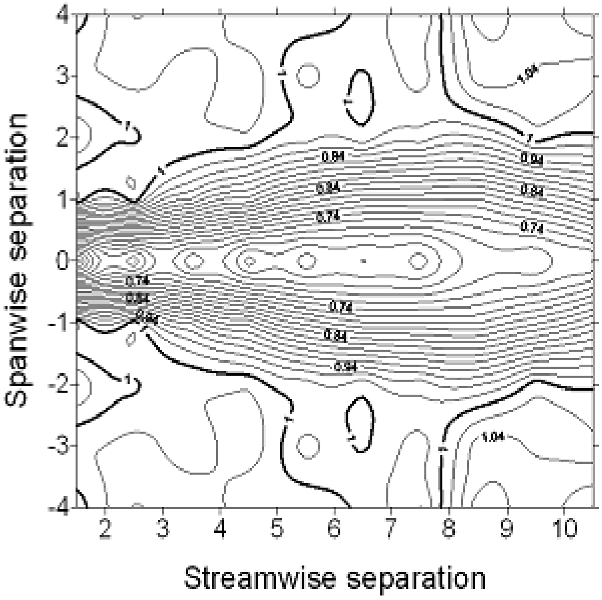
Fig. 6. Interference factors for alongwind mean force with separation



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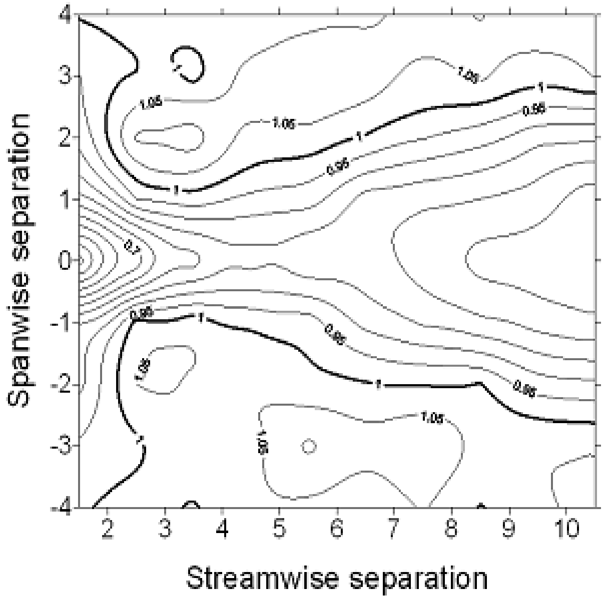

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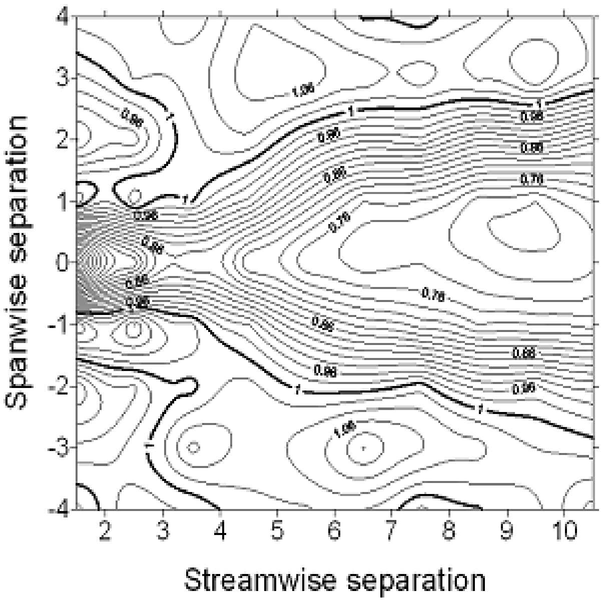

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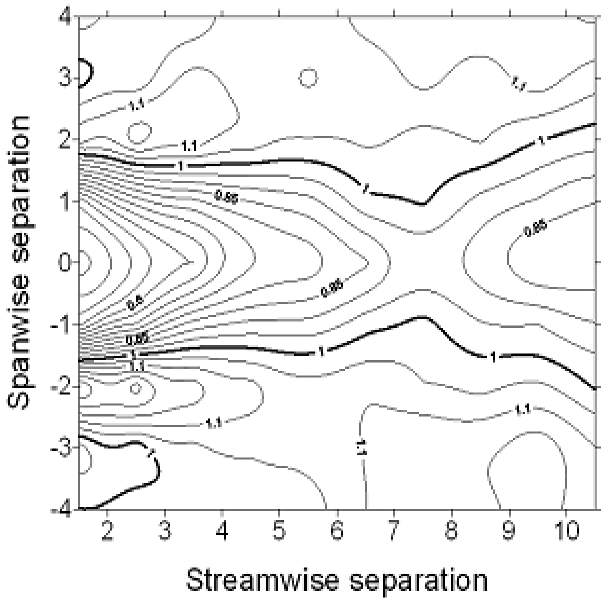

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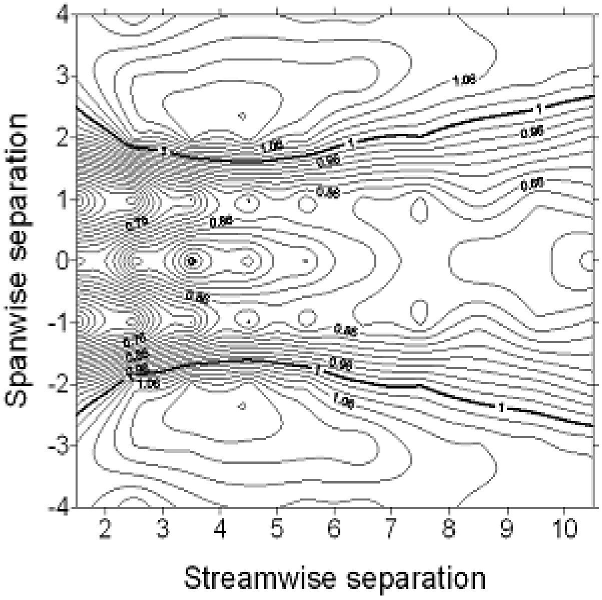
Fig. 7. Interference factors for alongwind fluctuating force with separation



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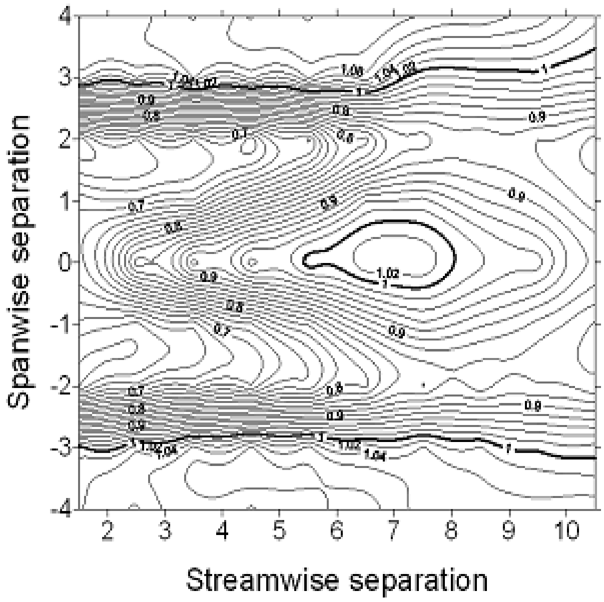

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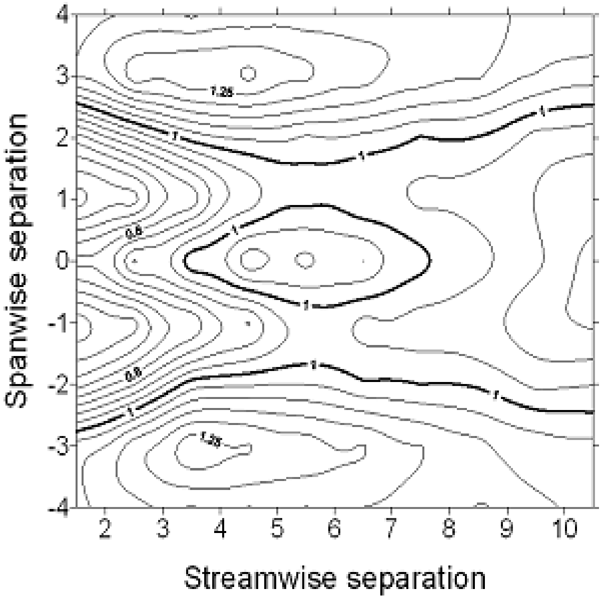

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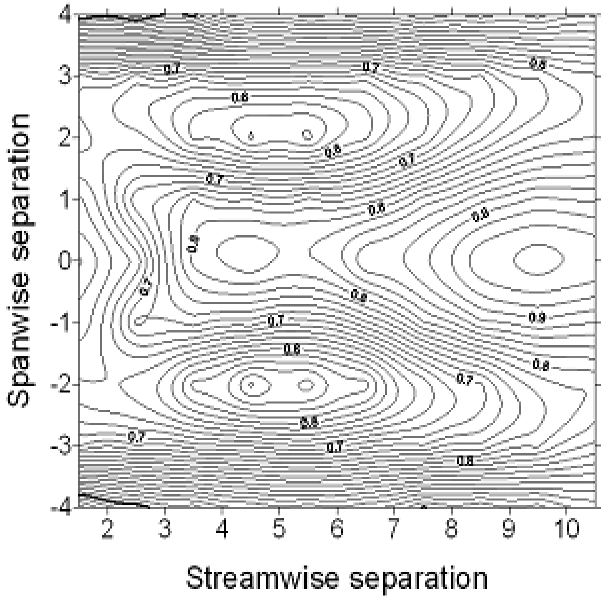

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Fig. 8. Interference factors for acrosswind fluctuating force with separation

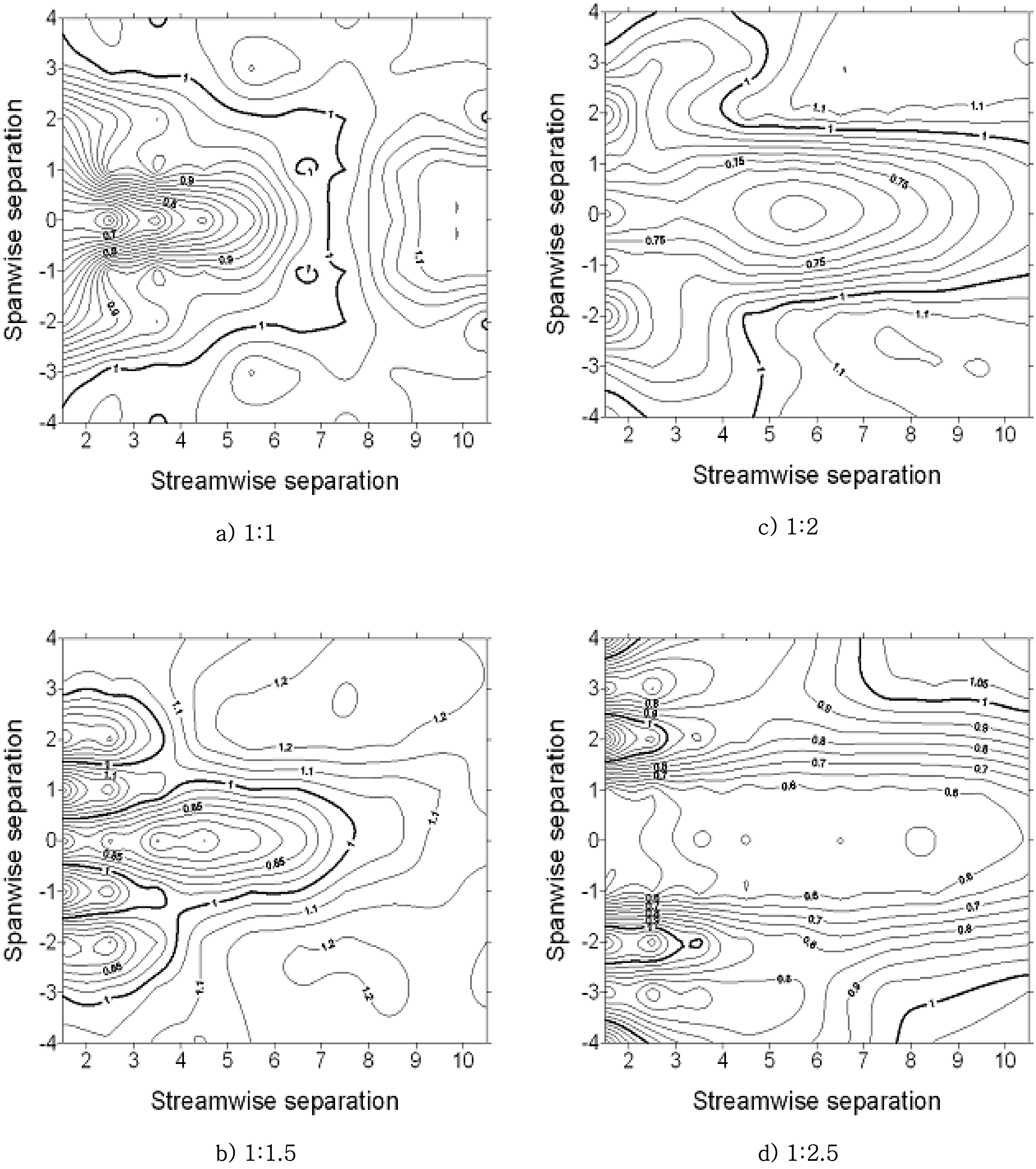

Fig. 9. Interference factors for torsional fluctuating force with separation