# Experimental Study of Temporal Scour around Spur Dikes

**Manish Pandey[1], Z. Ahmad[2], P. K. Sharma[3], Vinod Kumar[4]**

[1]*Student (M.Tech), Civil Department, IIT Roorkee-247667, INDIA.*
[2]*Civil Department, IIT Roorkee-247667, INDIA.*
[3]*Civil Department, IIT Roorkee-247667, INDIA.*
[4]*Student (M.Tech), Civil Department, IIT Roorkee-247667, INDIA*

## ABSTRACT

***Spur dike is a man-made hydraulic structure and constructed across the water flow (perpendicular or at an angle), for the purpose of protect the channel banks from the bed erosion and regulate the flow velocity. Estimation of temporal scour depth variation around spur dikes and effect of multiple spur dikes on scouring processes are very important for the purpose of safety and economical design of spur dikes. twelve experimental runs over fine sand bed ($d_{50}$=0.27 mm) will be represented in this paper; six runs for single spur dike and six runs for multiple spur dikes (three equidistance spur dikes) under clear water scour condition (for transverse length of 10 and 20 cm). The main aim of present experimental study is, to observe and calculate the scour behaviour (temporal and maximum scour depth) around single and multiple spur dike and also observe the effect of multiple spur dikes on scour phenomena. Flow pattern also observed by Acoustic Doppler Velocimeter (ADV). Temporal variation around spur dikes, effect of multiple spur dikes on scour phenomenon and flow behaviour around spur dike is explained in this study.***

***Keywords: Temporal scour variation, ADV and spur dike.***

## 1. INTRODUCTION

Spur dike is a man-made artificial hydraulic structure. Generally Spur dikes are fixed perpendicular or at an angle to the river or channel flow direction. Two important works of spur dikes are (i) to reduce the flow velocity and (ii) to protect the channel banks. There are several types of spur dikes such as submerged and non-submerged, permeable and non-permeable, attracting, deflecting and repelling. There are many varieties of its shape like straight, T-shape, L-shape and hockey shape. Scour defined as the removal of material from the water stream bed, when scour develop in the presence of any obstruction such as spur dike, abutment etc. is known as Local scour. Scour around spur dike is a common phenomenon in river engineering and a challenging problem for hydraulic researchers. Mainly scour responsible for failure of spur dikes, bridge piers and bridge abutments. Local scour divided into two categories: (i) Live-bed scour (when sediment usually is in motion) and (ii) Clear-water scour ($V/V_c < 1$, where V = average approaching velocity and $V_c$ = critical flow velocity for sediment). Temporal scour depth variation and maximum scour depth around spur dike is an important factor for the purpose of safety and prediction of scour depth equations. Flow behaviour around spur dike was observed by Acoustic Doppler Velocimeter (ADV). It gives three dimensional velocities of flow. In present study ADV was only used for maximum discharge, which was used at the frequency rate of 50 Hz for 20 seconds. In present study ADV fixed at 3.5 cm below the water surface. The three dimensional velocity components u, v, z along the X, Y, Z directions, respectively which shows the flow pattern around spur dike.

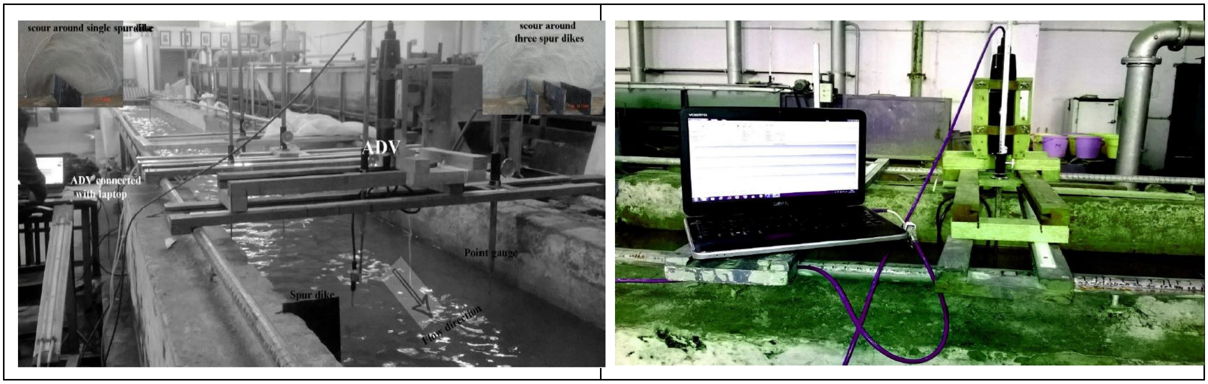
## 2. LITERATURE REVIEW

A large amount of literature available for sour around single spur dike, abutment and pier but very less literature available for scour around multiple spur dikes. Mathematical equations and formulae are generally same for spur dikes, abutments and piers. Many researchers contribute to describe the scour process and maximum scour depth in different conditions such as Garde et al. (1961), Gill (1972), Laursen (1963), Lim (1997), Melville (1988, 92, 97), Oliveto and Hager (2002-05), Dey and Barbhuija (2004-05), Hayashida et al. (2013) etc. Rahman et al. (2001) studied flow around pier and abutment. It was observed about flow pattern around abutment and pier with the help of ADV and plotted velocity contours. They observed that average velocities are more or less similar in both cases and described the flow pattern through velocity vectors. They also plotted the scour depth contours.

## 3. EXPERIMENTAL SETUP AND METHODOLOGY

All experimental works were carried out in the Hydraulic Engineering laboratory of Civil Engineering Department, Indian Institute of Technology ROORKEE. Hydraulic parameters were shown in table (1) for all experimental runs. A 24 m long, 1.0 m wide and 0.50 m deep fixed bed masonry flume was selected for that experimental works. The longitudinal slope of the flume is equal to 0.0005. In present experimental works, discharge measured by a sharp crested weir, which was provided at the end section of the flume. A working section of size 4m x 1m x0.45 (length x width x depth) was prepared for the experiments. The working section of the flume was started from 13.7m downstream to the flume entrance. Partially submerged and impermeable spur dikes having transverse lengths of l=10cm, 20cm and thickness 2 mm were selected for the all experiments. Spur dikes were fixed at perpendicular across the water flow.

Experiments were done for single and multiple spur dikes having 10 cm and 20 cm transverse length. First spur dike always fixed at 15.65m from flume entrance and spacing between spur dikes which was equal to transverse length (l). Twelve experiments were represented in this paper six for single spur dike and six for multiple spur dike having 10 cm and 20 cm transverse length. Three different discharges $Q_1$, $Q_2$ and $Q_3$ were used for every location of spur dike such as single spur dike (l=10 and 20 cm) and same for multiple spur dike's case. So this paper represented the total number of 12 experimental runs.




All experiments were conducted for fine sand, under clear water scour conditions (V/Vc) < 1 having 0.27mm median diameter ($d_{50}$), $d_{84}$= 0.32mm, $d_{16}$=0.213mm, σ= $\sqrt{(d_{84}/d_{16})}$ =1.23. V is approaching mean velocity and Vc is critical shear velocity for sediment, Vc defined by Lauchlan and Melville (2001) equation (1);

$$V_c / V_{*c} = 5.75 \log(y/k_s) + 6 \quad (1)$$

**Table. 1**

| Run | *s(m)* | *y(m)* | *B(m)* | *l(m)* | *$d_{50}$(mm)* | *Q(m3/s)* | *V(m/s)* | *$V/V_c$* | *$d_{s1}$(cm)* | *$d_{s2}$(cm)* | *$d_{s3}$(cm)* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | - | 0.1 | 1 | 0.1 | 0.27 | 0.0159 | .159 | 0.63 | 7.7 | - | - |
| 2 | - | 0.1 | 1 | 0.1 | 0.27 | 0.0188 | .188 | 0.75 | 9.2 | - | - |
| 3 | - | 0.1 | 1 | 0.1 | 0.27 | 0.0210 | .210 | 0.84 | 13.8 | - | - |
| 4 | 0.1 | 0.1 | 1 | 0.1 | 0.27 | 0.0159 | .159 | 0.63 | 4.1 | 2.1 | 0.6 |
| 5 | 0.1 | 0.1 | 1 | 0.1 | 0.27 | 0.0188 | .188 | 0.75 | 7.6 | 2.6 | 1.9 |
| 6 | 0.1 | 0.1 | 1 | 0.1 | 0.27 | 0.0210 | .210 | 0.84 | 9.6 | 5.7 | 2.1 |
| 7 | - | 0.1 | 1 | 0.2 | 0.27 | 0.0159 | .159 | 0.63 | 6.5 | - | - |
| 8 | - | 0.1 | 1 | 0.2 | 0.27 | 0.0188 | .188 | 0.75 | 8.3 | - | - |
| 9 | - | 0.1 | 1 | 0.2 | 0.27 | 0.0210 | .210 | 0.84 | 11.2 | - | - |
| 10 | 0.2 | 0.1 | 1 | 0.2 | 0.27 | 0.0159 | .159 | 0.63 | 6.9 | +2.9 | 0.1 |
| 11 | 0.2 | 0.1 | 1 | 0.2 | 0.27 | 0.0188 | .188 | 0.75 | 9.9 | 1.5 | 0.4 |
| 12 | 0.2 | 0.1 | 1 | 0.2 | 0.27 | 0.0210 | .210 | 0.84 | 12.3 | 3.1 | 1.9 |

## 4. MODELING OF TEMPORAL SCOUR DEPTH AROUND SINGLE SPUR DIKE: RESPECTIVELY

(Kothyari et al. 2007) derived a formula for temporal scour depth around singular as well as multiple spur dikes, pier, abutment (rectangular and slopping). According to this relationship, temporal scour depth mainly depends upon standard deviation ($\sigma = d_{84}/d_{16})^{1/2}$ of sediment, time variation and difference between actual densimetric particle Froude number and densimetric particle Froude number of scour entrainment ($F_d$- $F_{d\beta}$).

Kothyari et al. (2007) gave following relationship for the temporal variation of scour,

Where, $$d_{ss} = (d_{st} / z_R) = 0.272 \cdot \sigma^{-1/2} \cdot (F_d - F_{d\beta}) \cdot \log T \quad (2)$$

$$F_{d\beta} = [F_d - 1.26 \cdot \Sigma \cdot \Sigma_s \cdot \Sigma_{ca} \cdot \beta^{\Sigma/4} \cdot (Rh/d50)^{1/6}] \cdot \sigma^{1/3} \quad (3)$$

$$F_{di} = 2.33 \cdot D_*^{-0.25} \cdot (R_h / d_{50})^{1/6} \qquad \text{For, } D_* \leq 10 \quad (4)$$

$$F_{di} = 1.08 \cdot D_*^{1/12} \cdot (R_h / d_{50})^{1/6} \qquad \text{For, } D_* \geq 150 \quad (5)$$

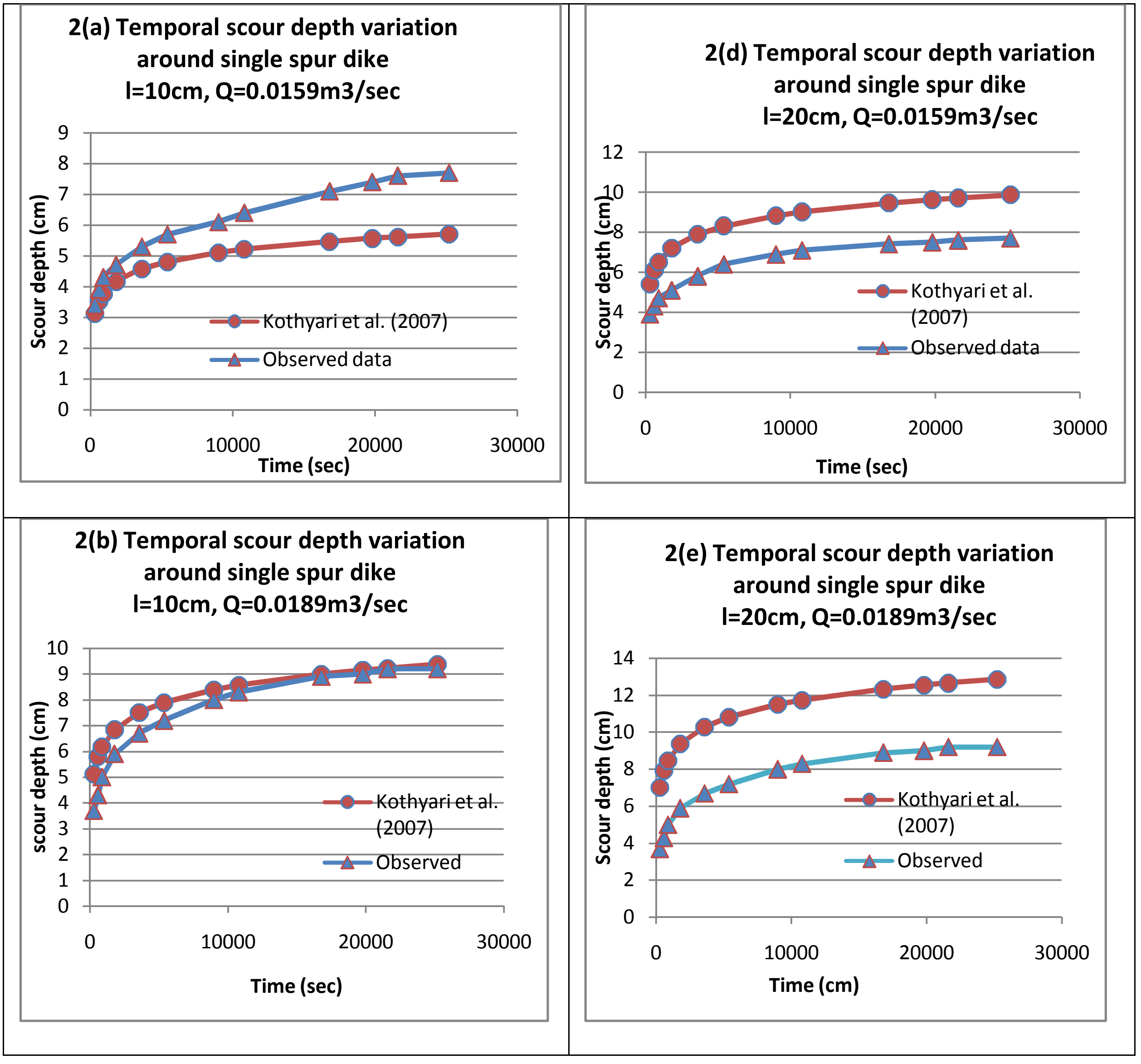
$$F_{di} = 1.65 \cdot (R_h / d_{50})^{1/6} \qquad \text{For, } 10 < D_* < 150 \quad (6)$$

$$F_d = V / (g' \cdot d_{50})^{1/2} \quad (7)$$

Here $D_*$ is dimensionless grain size, which is equal to; $D_* = (g/v^2)^{1/2}$, $g' = [(\rho_s - \rho)/\rho] \cdot g$ known as relative gravitational acceleration; $\rho_s$ is sediment density; $\rho$ is fluid density; $g$ is gravitational acceleration; υ is kinematic viscosity ($10^{-6}$ $m^2/sec$). $\Sigma$, $\Sigma_s$, $\Sigma_{ca}$ are element shape, submergence and cascade parameter respectively. For singular spur dike $\Sigma=5/4$, $\Sigma_{ca}=1$ and $\Sigma_s=(s_1/y)^{0.3}$; $\beta=b_{eff}/B$. $s_1$ represents the effective height of spur dike and $b_{eff}$ represents the effective spur dike width relative to the direction of approach flow. In equation (2): $d_{ss}$is dimensionless scour depth, $d_{st}$is temporal scour depth at time $t$, $T=t/t_r$; $t_r = z_R / [\sigma^{1/3} (g' d_{50})^{1/2}]$and $z_R$ is reference length = $(y \cdot b^2)^{1/3}$; y represents the approach flow depth and b is length of spud dike. This formula also applicable for three equidistant spur dikes but except $\Sigma_{ca}=0.90$ for 90° angle approach flow direction and flume wall.

## 5. CONCLUSION

The result of present experimental works, six runs around single spur dike and six runs around equidistance three spur dike (multiple spur dikes). All twelve runs were conducted for fine sand bed under clear water condition. In this paper, it was observed that maximum scour depth located at the noses of spur dike but it was located between noses of spur dike and spur dike wall junction for equidistance three spur dike's case. Temporal scour depth variation around single and multiple spur dikes were computed by relationship of Kothyari et al. (2007) and results showed good agreements with the observed and simulated scour depth data with ±25% error, shown in **fig.(2) and fig. (3).** Maximum scour depth around single and multiple spur dikes was also calculated by point gauge. For equidistance three spur dikes, maximum equilibrium scour depth around first spur dike always greater as compare to the second and third spur dike shown in table 1. Maximum scour depth at equilibrium stage increasing with increase of discharge and transverse length of spur dike. Maximum equilibrium scour depth around single and multiple spur dikes shown in **table (1)**.



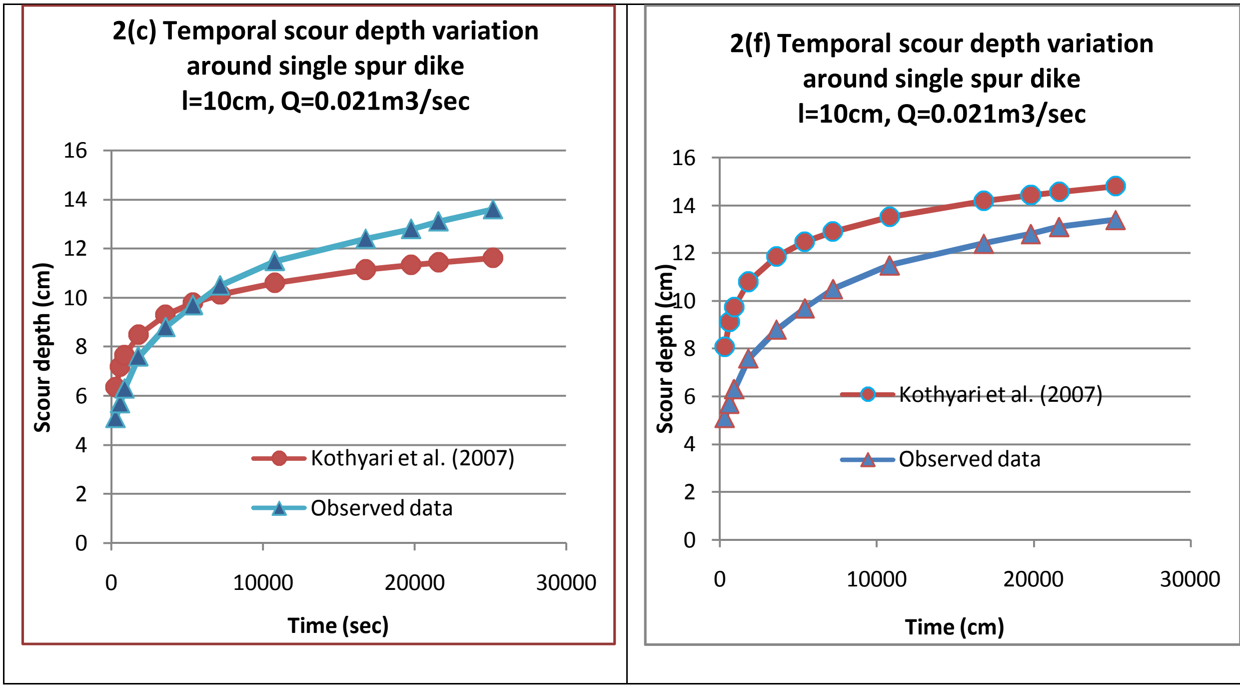
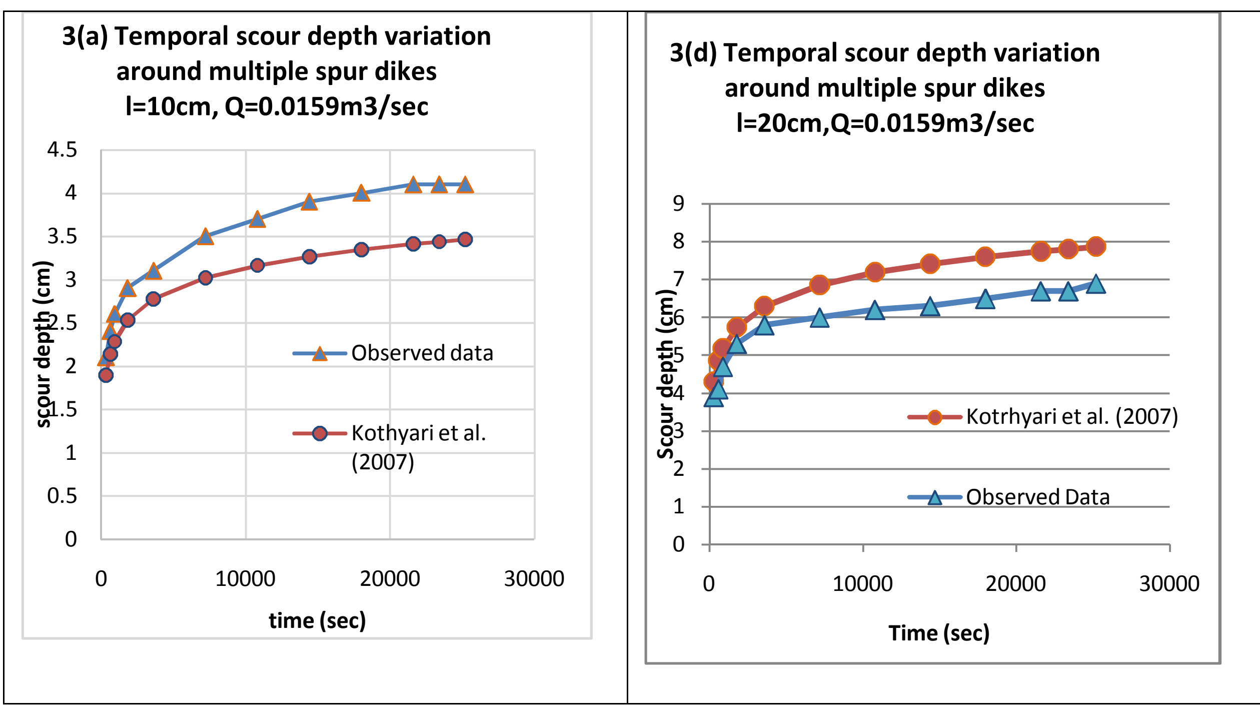



**Fig. (2) Temporal scour variation around single spur dike; 2(a-c) for *l*=10cm and 2(d-f) for *l*=20cm**



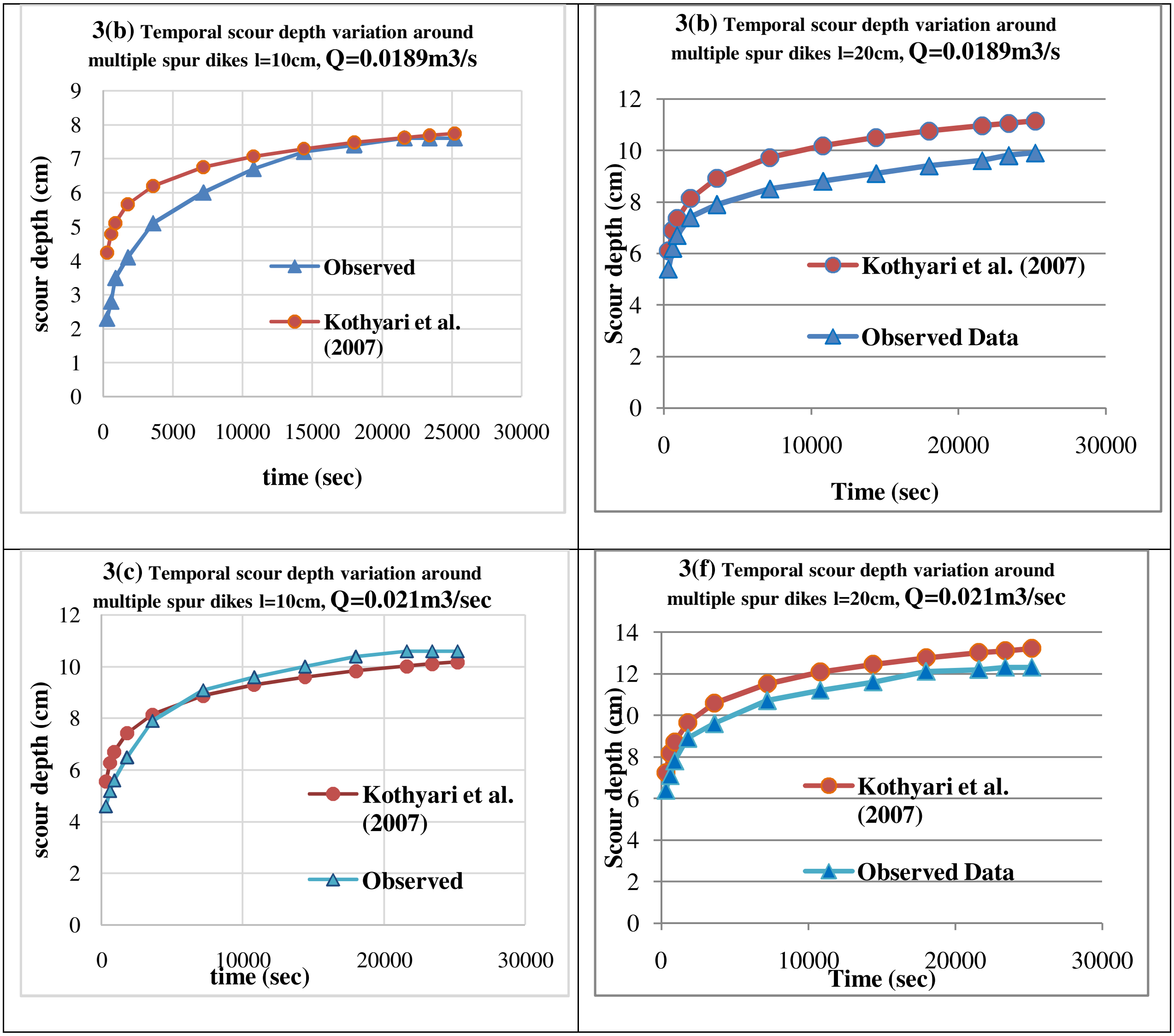



**Fig. (2) Temporal scour variation around single spur dike; 2(a-c) for *l*=10cm and 2(d-f) for *l*=20cm**

## REFERENCES

[1] Dey, S. and A. K. Barbhuiya (2005). "Time variation of scour at abutments." Journal of Hydraulic Engineering 131(1): 11-23.

[2] Froehlich, D. C. (1989). "Local scour at bridge abutments". Hydraulic Engineering (1989), ASCE.

[3] Hayashida, H., Muto, Y., Tazoe, S., and Tamura, T, . (2013). "Scour and Deposition around Spur Dykes with head work".Taylor & Francis Group, London, ISBN 978-1-138-00062-9.

[4] Kothyari, U. and K. Ranga Raju (2001). "Scour around spur dikes and bridge abutments." Journal of hydraulic research 39(4): 367-374.

[5] Kothyari, U. C., et al. (2007). "Generalized approach for clear-water scour at bridge foundation elements." Journal of Hydraulic Engineering 133(11): 1229-1240.

[6] Marson, C., Fiorotto, V., Caroni. E. (2006). "Clear water scour analysis around groins and bridge abutments, Taylor & Francis Group plc, London, 1749-1775.

[7] Masjedi, A., Dehkordi, V., Alinejadi, M., Taeedi, A. (2010)."Experimental study on scour depth in around a t-shape spur dike in a 180 degree bend". World Applied Sciences Journal, 10(10): 1146-1152.

[8] Oliveto, G. and W. H. Hager (2002). "Temporal evolution of clear-water pier and abutment scour." Journal of Hydraulic Engineering 128(9): 811-820.

[9] Vaghefi, M., Ghodsain, M., and Nayshaboori, S. (2009)."Study on the effect of a T-shaped spur dike length on scour in a 90° channel bend". The Arabian Journal for Science and Engineering, 34, 2B, 337-348.

[10] Zhang, H. and H. Nakagawa (2008). "Scour around spur dyke: recent advances and future researches." Annuals of the Disaster Prevention Research Institute, Kyoto Univ 51: 633-652.