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Determination of Active Earth Thrust on Fascia Retaining Wall

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ABSTRACT : *High transportation demand has led to widening of existing highways to increase the right of way. Due to limited space available at site, most of the times retaining walls are required to be constructed in front of previously stable face. The design methodology for earth retaining structures placed adjacent to stable wall with constricted space is not very evident at present. Model experiments were conducted in the laboratory to find out the pressure on these walls.The present work essentially consists of developing user friendly theoretical approach to diagnose such walls and its verification in the laboratory.*

KEYWORDS : *Fascia Retaining wall, Active Earth Thrust, Laboratory Model Test, Aspect Ratio,*

I. INTRODUCTION

A stabilized wall when constructed in front of already constructed wall or existing rock face results in an extremely narrow backfill width between the retaining wall and rock face. Such newly constructed wall is called Fascia Retaining wall. Due to narrow backfill width, arching theory predicts that the vertical forces within the backfill will be reduced. The decrease in vertical pressure will result in corresponding decrease in lateral earth pressure exerted upon the retaining wall. To study the fascia wall, the aspect ratio is taken into account which is defined as the ratio of narrow space (width) between the two walls to the height of the retaining wall. From figure, Aspect Ratio $=\frac{B}{H}$.

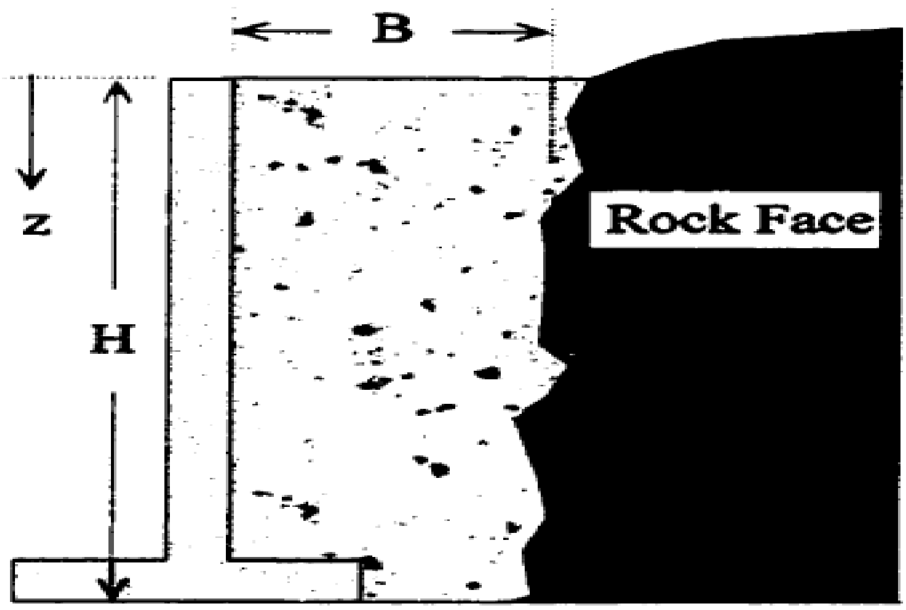

Figure 1 Fascia Retaining wall

Literature Survey

A number of researchers: Frydman and Keissar (1987), Take and Valsangkar (2001), Kniss, Yang, Wright and Zornberg (2007), Yang, Gupta and Zornberg (2009), Fan and Fang (2010) demonstrated that earth thrust acting on a Fascia Retaining wall depends mainly on two factors viz. boundary constraint and narrow backfill width between the two walls. Only two previous experimental programmes dealing specifically with fascia retaining walls have been reported in the literature. The present study, therefore, provides a useful addition to the database of experimental earth pressure studies.

Take and Valsangkar (2001) performed a series of centrifuge tests to study the factors affecting the calibration of subminiature boundary pressure cells to investigate the reduction in lateral earth pressure within the narrow backfill width of an unyielding fascia retaining wall. Frydman and Keissar (1987) presented the study of the lateral pressure transferred to a rigid retaining wall by granular fill confined between the wall and an adjacent rock face. They found that a pressure acting on the wall, when it reaches an active condition by rotating about its base, appears to be less sensitive to small variations in placement conditions. Yang and Liu (2007) studied earth pressure acting on the narrow retaining walls by Finite element analysis. The trend of decrease of earth pressures as the decrease of wall aspect ratios was observed. When aspect ratio is $L/H < 0.3$, the failure mode is found to transform from internal failure to external failure. Kuo-Hsin Yang and J.G. Zornberg (2009) have discussed the limit equilibrium method to calculate the earth pressure on fascia retaining wall. Leshchinsky, Hu, and Han (2003) and Lawson and Yee (2005) performed limit equilibrium analyses to study the effects of wall aspect ratio on the horizontal earth pressure coefficients.

Theoretical Formulation of the Problem

Calculation for Earth Thrust is made by using Analytical Solution by considering various forces acting on the failure wedge and calculating the location of critical failure wedge with respect to horizontal. The earth thrust corresponding to this critical wedge will give maximum earth thrust acting on the wall. The calculation is done by smooth retaining wall with no wall friction angle ($\delta = 0°$).

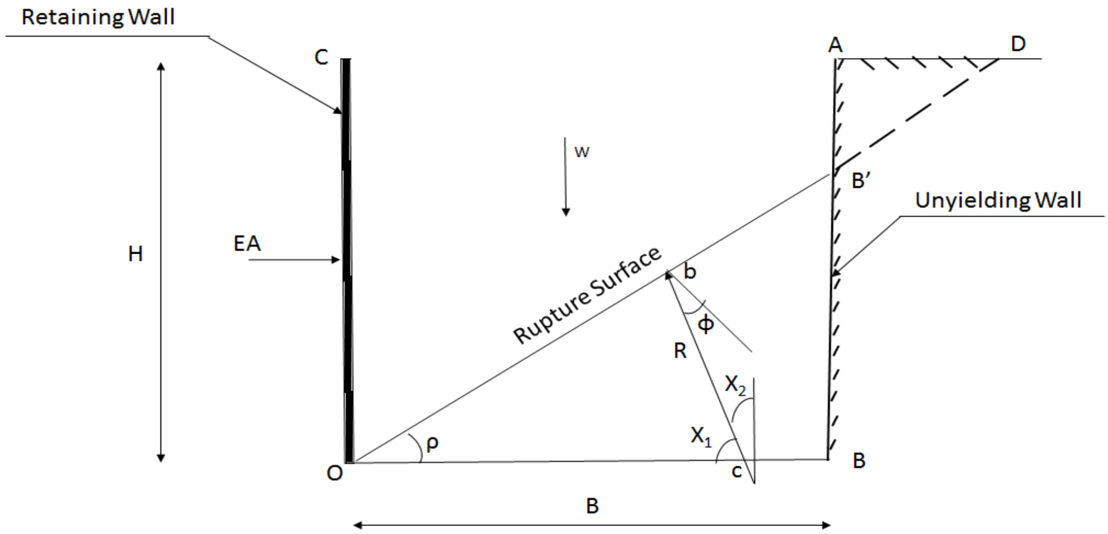

Figure 2. Forces Acting on the Failure Wedge

Figure 2 represents, the various forces acting on the failure wedge. As the wall is considered to be smooth the active earth thrust force will act horizontally on the retaining wall. The various parameters shown in figure are as explained below:

EA = Active Earth Thrust in kN
R = Resultant Force acting at right angles to failure wedge in kN
W = weight of soil within the failure wedge in kN
ρ = angle made by failure wedge with horizontal in degrees
ϕ = angle of internal friction of soil in degrees
H = height of the retaining wall in metres
B = width of backfill soil between the retaining wall and unyielding wall
X1 and X2 = angles made by resultant w.r.t horizontal and vertical respectively

By considering the geometry of failure wedge as shown in Fig. 2, the expression for earth thrusts is obtained as follows:

$$\text{Angle, } X_1 = [180° - (boc + cbo)]$$
$$= \{180° - [\rho + (90 - \phi)]\}$$
$$= 180° - \rho - 90 + \phi$$
$$\text{Angle, } X_1 = 90° - (\rho - \phi)$$

Also,
$$X_1 + X_2 = 90°$$
$$X_2 = 90° - X1$$
$$X_2 = 90° - (90° - \rho + \phi)$$
$$\text{Angle, } X_2 = (\rho - \phi)$$

From the three forces namely W, EA and R

$$180^\circ = X_3 + 90^\circ + X_2$$

$$180 = X_3 + 90^\circ + (\rho - \phi)$$

$$X_3 = 90 - \rho + \phi$$

$$\text{Angle, } X_3 = 90^\circ - (\rho - \phi)$$

Now to calculate the value of magnitudes of forces: -

From Sine Rule, We have

$$\frac{EA}{\sin X2} = \frac{W}{\sin X3}$$

$$EA = W \times \frac{\sin X2}{\sin X3}$$

$$\text{Therefore, } EA = W \times \frac{\sin(\rho-\phi)}{\sin[90^\circ-(\rho-\phi)]}$$

$$EA = W \times \frac{\sin(\rho-\phi)}{\cos(\rho-\phi)}$$

$$EA = W \times \tan(\rho - \phi)$$

Above equation represents the Earth thrust value which can be calculated either by differentiating above equation w.r.t 'ρ' value and equating it to zero or by taking various values of 'ρ' and calculating the corresponding value of earth thrust. The value of 'ρ' which gives maximum value of Earth thrust should be used for design of such walls. In this study the earth thrust is calculated by taking various values of 'ρ'.

II. EXPERIMENTAL INVESTIGATION

Selection of Soil Sample

Grain size distribution affects the behavior of sand masses during backfilling. The cohesionless dry sand is critical for its earth pressure behavior against retaining wall. Hence cohesionless dry sand is selected whose properties are discussed in Table 1

Table1. Index Properties of Clean Sand

Sr.No.	Index Properties	Values
1.	Density ρ	1.99 gm/cc
2.	Specific Gravity G	2.726
3.	Coefficient of Curvature C_c	0.868
4.	Coefficient of Uniformity C_u	3.235
5.	Phi, ϕ	32.85
6.	e_{max}	0.6285
7.	e_{min}	0.3806

Experimental set up

The experimental set up consists of a retaining wall model comprises of a retaining wall of MS plate (1210 x 1000 x 5) mm size fixed at the bottom by using bolting arrangement, unyielding wall of same size which is held immobile by fixing it to a grooving arrangement made at five different locations, LVDT arrangement is to measure horizontal displacement of wall. 5 LVDT's are used; 3 in the same line at the top (800mm), one at the center (400mm) and one at the bottom (200mm), Displacement display unit to display the deflection of retaining wall after backfilling the sand in the model tank.

All the components of the model retaining wall are shown in the Figure 3.

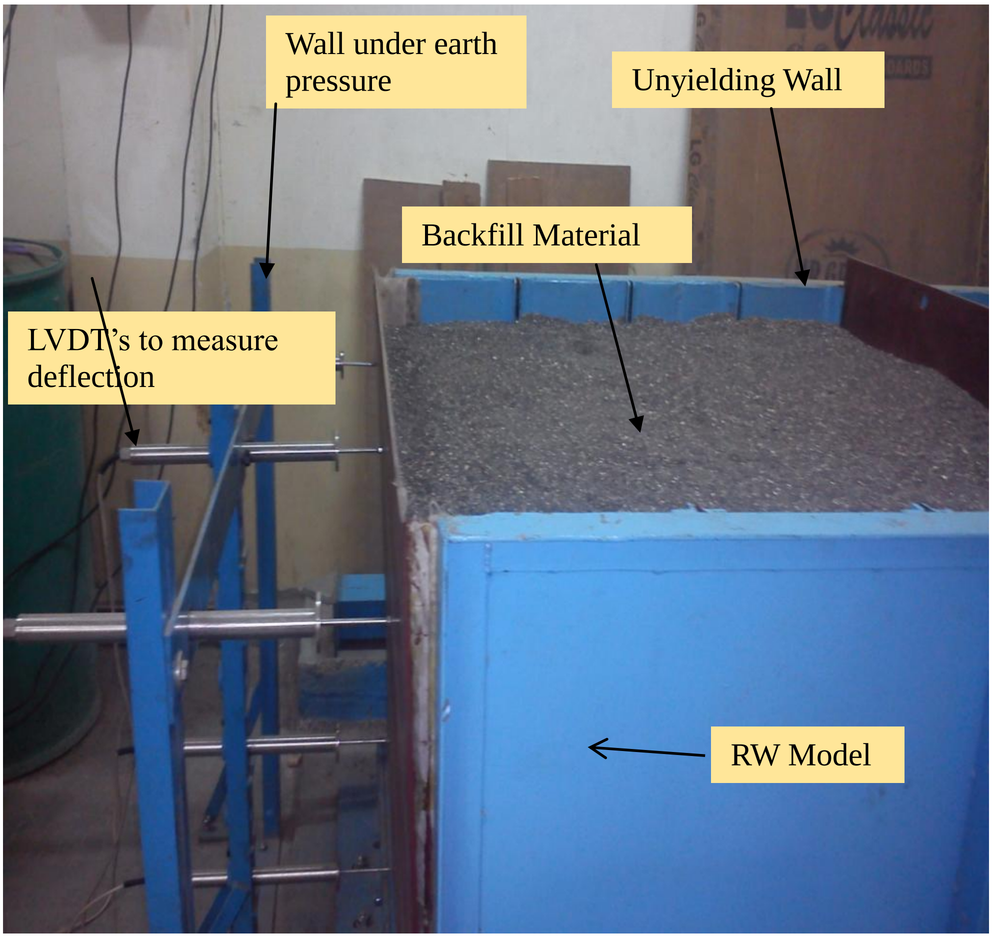

Figure 3. Retaining wall Model

Testing Program

Ten tests in total (*cf.* Table 2) are conducted on the retaining wall model to study the effect of aspect ratio on the calculated earth thrust. Tests are planned for different aspect ratio ranging from 0.25 to 1.25.

Table 2 Testing Program

Sr. No.	Retaining Wall Dimensions	Aspect Ratio (L/H)	Test Condition
01.	(1000 x 1210 x 5) mm	0.25	Full Backfill with 0.8m Height
02.		0.50	Full Backfill with 0.8m Height
03.		0.75	Full Backfill with 0.8m Height
04.		1.00	Full Backfill with 0.8m Height
05.		1.25	Full Backfill with 0.8m Height

III. RESULTS AND DISCUSSION

The experimental work was carried out in order to study the effect of Aspect Ratio on evaluated earth thrust on retaining wall model. For this purpose total five tests were conducted on dry Cohesionless soil for full backfill with 0.8 m height for different Aspect Ratios ranging from 0.25 to 1.25. All the tests were conducted over a smooth retaining wall for no wall friction angle i.e., δ = 0˚.

(a) For Aspect Ratio = 0.25

The Aspect Ratio is kept as 0.25 by changing the position of unyielding wall and placing it at a distance of 0.25 from retaining wall (RW) so that the ratio of L/H = 0.25. The values of deflection of RW only due to backfill are taken by fixing the LVDT's over the height of RW at three different locations.

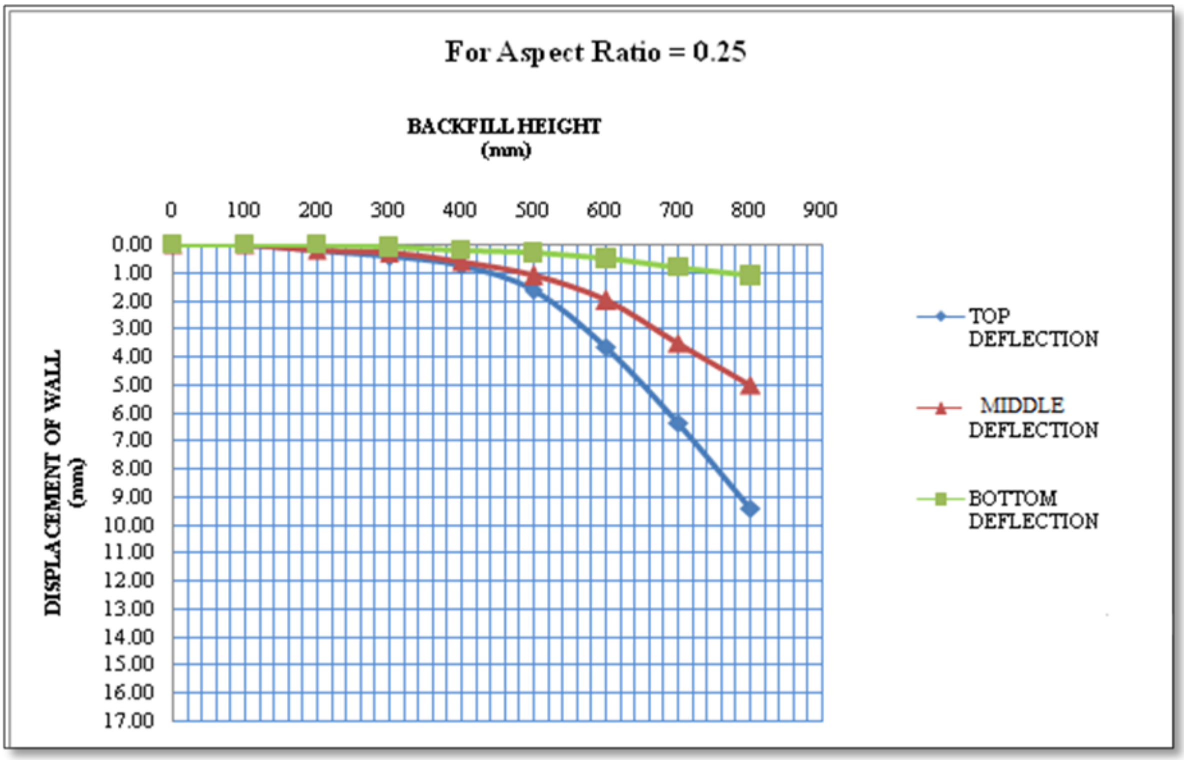

Figure 4. Deflections at various levels

Figure 4 shows the plot of displacement of wall (mm) versus backfill height (mm). The three curve lines of green, orange and blue colour represent the deflection curve for bottom, middle and top location of LVDT's

The maximum deflection values of 9.43 mm, 5.00 mm and 1.10 mm are observed at top, middle and bottom location of LVDT's respectively; up to a height of 150 mm, wall does not deflect significantly. The deflection of wall for a height up to 400 mm at middle level is slightly less than that at the top level and it is about 0.82 times the deflection at top level. The variation in deflection values for three different locations increases as the backfill height increased. The maximum deflection values observed at a height of 800 mm at bottom and middle location are about 0.12 and 0.53 times deflection at top level.Similar readings were taken for other aspect ratios and the displacement of the wall was measured for backfill heights with the interval of 0.1m. For aspect ratio of 0.5, it is observed that maximum deflection values at top, middle and bottom location of LVDT's are 11.80 mm, 6.80 mm and 2.70 mm respectively, up to a height of 250 mm value deflection of wall is observed to be very negligible and all three curves more or less merge with each other. The wall deflection can be observed clearly in the graph from a wall height of 300 mm and above. The deflection of wall for a height of 400 mm at bottom level and middle level is slightly less than the top level and it is about 0.41 and 0.68 times the deflection at top level. The deflection of wall from height of 600 mm at middle level is observed to vary from 0.50 to 0.58 times the top deflection whereas it is found to be 1.82 to 2.5 times the bottom deflection.

Similarly for aspect ratio 0.75, the maximum deflection values recorded were 16.50 mm, 9.20 mm and 4.00 mm at top, middle and bottom location of LVDT's respectively. No deflection is observed for a backfill height of 100 mm. The wall deflection observed up to a height of 300 mm is less than 1 mm. The deflection of wall for a height of 400 mm at bottom and middle level is less than the top level and it is about 0.16 and 0.58 times the deflection at top level respectively. The deflection of wall from height of 600 mm at middle level is observed to varies from 0.73 to 0.50 times the top deflection whereas it varies from 1.81 to 2.3 times the bottom deflection.

The maximum deflection values were 18.40 mm, 8.90 mm and 5.90 mm at top, middle and bottom location of LVDT's respectively for aspect ratio =1. The wall deflection observed up to a height of 300 mm continues to be less than 1 mm. The deflection of wall at a height equal to half the height of wall is nearly the same at all locations of LVDT's and it can be seen from graph that up to the backfill height equal to 400 mm all three curves are coinciding with each other. The deflection of wall from height of 600 mm at middle level is observed to vary from 0.79 to 0.48 times the top deflection whereas it varies from 1.84 to 1.51 times the bottom deflection.

(b) For Aspect Ratio = 1.25

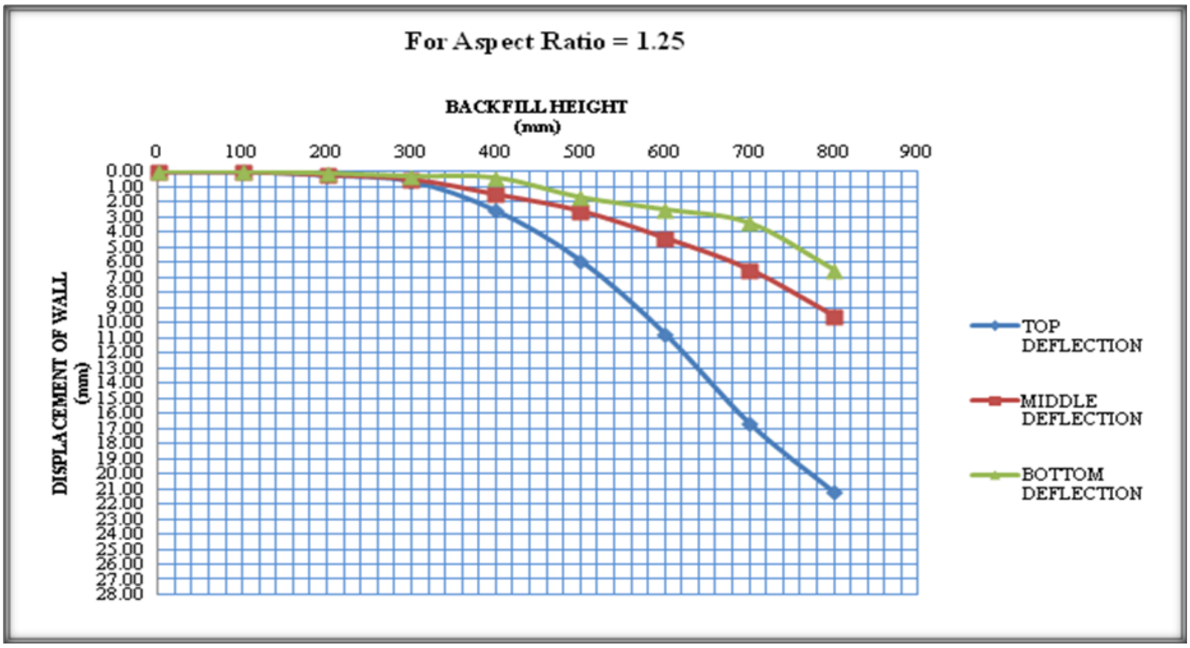

Figure 5 Deflections at various levels

It is observed from figure 5, that maximum deflection values of 21.23 mm, 9.60 mm and 6.50 mm is observed at top, middle and bottom location of LVDT's respectively. The wall deflection up to a height of 300 mm is nearly the same at all location of LVDT's and thus all the three curves coincide with each other. The deflection of wall at top level is more and the variation of values from middle and bottom level is more. The deflection value at top level is 2.38 to 2.21 times that at the centre deflection whereas it varies from 8.92 to 3.27 times the bottom level deflection for height of 400 mm to 800 mm. The maximum deflection values at bottom and middle level of LVDT's are 0.31 and 0.45 times the top level LVDT's deflection values.

Calculation of Earth Thrust from Experimentation Values

Earth Thrust is calculated by using deflections values observed during experiment conducted on the model developed in the laboratory. The earth thrust is calculated for each of the aspect ratios considered in the present work. The results obtained from experimental values are compared with those obtained by using analytical method and are tabulated as below.

Table 3 Comparison of Earth Thrust Values

Sr. No.	Aspect ratio	EA (kN) (Theoretical)	EA (kN) (Experimental)	Tolerance (%)
1	0.25	1.721	1.685	2.09
2	0.50	1.888	1.797	4.82
3	0.75	1.888	1.833	2.91
4	1.00	1.888	1.865	1.22
5	1.25	1.888	1.879	0.48

IV. CONCLUSION

A methodology is developed for design purposes to estimate the earth pressure on fascia retaining wall which is then verified by model tests and the tolerance is remarkable, demonstrating that the proposed method can be applied for designing such walls in the field.

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