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MANUAL PILE EXCAVATION USING BLASTING TECHNIQUE IN NEPAL

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ABSTRACT

Pile foundations are integral to the construction of modern bridges, especially in challenging terrains and steep slopes where machine excavation is impractical. This research paper focuses on the practice of manual excavation of pile holes using blasting materials. The study was conducted as part of the KathmanduTerai/Madhesh Fast Track project in Nepal, where 106 piles were excavated manually for bridges. The paper presents findings on the blasting design, equipment used, and the effect of blasting on different types of stones, including weathered mudstone, mudstone, weathered sandstone, sandstone, weathered siltstone, and siltstone. The results demonstrate the effectiveness of manual excavation with blasting in breaking down stones and achieving desired blast effects.

OVERVIEW

The pile foundation has played a vital role in the evolution and effectiveness of bridge construction through the ages. History has seen the evolution of bridges from wood to steel to RCC bridges on different places, on rivers, and on mountains. Most of the modern bridges are constructed on pile foundation. In the modern world most of the pile are excavated through the machines either through rotatory drilling or percussion drilling. But the practice of excavating pile holes manually through hand tools like chisel, hammer spades, shovels and using blasting materials is not seen much. Manual dug holes can be more economical and easier to do where there is steep slope and machine use is difficult because of the topography of the land. In this manual dug pile on stone for convenient and fast work blasting material (Explosives) is used. Depending upon the class, or the type of stone blasting materials are used. The machine used in the manual excavation also doesn't cost much and is much cheaper than that of mechanical drilling machines.

The practice of manual excavation is environmentally good as we don't have to use chemicals that harm the river and stream. This kind of excavation is generally practiced where the level of ground water is well below and if there is presence of ground water then the volume shall be less as the large volume of water might slow down the excavation process. This manual excavation is very effective on the high slopes and the pile having diameter more than 1.5 m. As in steep slopes we cannot take the drilling machines due to the topographic problems.

Here in Kathmandu-Terai/Madhesh Fast Track Package No.2 (KTFT-2) for bridges #35 #36 #37 #38 we have practiced the excavation of pile manually. There are 106 piles in this package among which most of the piles are of diameter 2m and 2.5 m whereas only few piles are with diameter 1.5 m. All the piles will be excavated manually using manual excavation tools. In this manual excavation we need to have explosives if there are hard stones. The explosives are used based on the nature of the stone and their classes. In this project we have mainly weathered mud stone, mud stones, weathered sand stones, sand stones, weathered silt stone and silt stones. On the start of the excavation the quantity of the explosives was calculated depending upon the trail basis. We started blasting using blasting material based on the hole drilled and nature of the stone present. The size of the drill hole is 40 mm, but the length of the hole varies depending upon the place. Following to photos are the blasting plan for the 2 m diameter hole and 2.5-meter diameter hole.

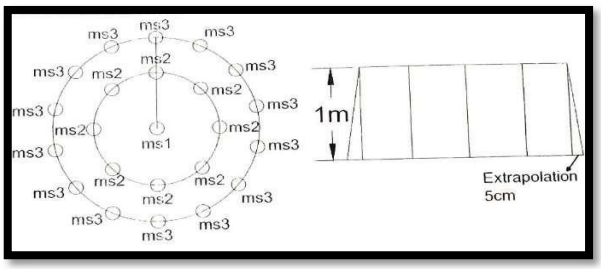

Figure 1: Blasting Plan for 2m hole

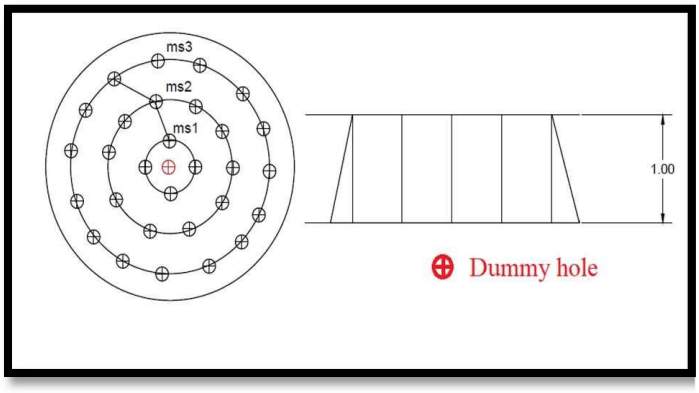

Figure 2: Blasting Plan for 2.5 m hole

BLASTING DESIGN

After manual excavation meets weak and slightly weathered stone strata, shallow hole loose blasting method should be adopted, and electric detonators should be used to detonate, and non-electric millisecond detonator should be used to detonate deep hole piles. For soft stones, the blast hole depth shall not exceed 1m, and for hard stone, it shall not exceed 1.2 m. The number, location and oblique cutting direction of blast holes should be determined according to the cross-section direction of the stone stratum. The middle group should focus on coring, and the sides should be obliquely inserted and dug around. Excavate the middle first, then the surrounding, and work continuously in shifts.

1) EXCAVATION SECTION AND BLAST HOLE LAYOUT (CYCLIC FOOTAGE IS DESIGNED AS 1M).

The optimal blast hole depth is selected based on the principle of minimizing the time spent on each driving shift and considering the hardness of the stone. The fundus of the peripheral hole and the auxiliary hole are on the same plane to ensure that the excavation surface is flat. The cutting blast hole is 10cm deeper than the fundus of the auxiliary hole, and the drilling depth is adjusted according to the blasting effect (the cutting hole adopts straight hole cutting). The blast hole adopts standard diameter (the blast hole diameter is 40mm, and the diameter of the roll is 32mm), and the central cutting hole adopts straight hole cutting. The peripheral holes are arranged along the excavation contour, and the auxiliary holes are staggered between the peripheral holes and the cutting holes and are drilled perpendicular to the excavation surface. The blast holes are arranged in a staggered manner in a quincunx shape, and the distance between rows is equal to 0.86 times the distance of the blast holes in the same row. The distance between the eye funds of the middle cutting eye is controlled at 20cm. The numbers 1, 2 and 3 on the side of the blast hole indicate the detonation sequence. The detonating network is divided into 2 ~ 4 clusters to connect the detonator and finally detonate with the detonating primer. The hole is blocked with tamping plug (sand) with a length of 20cm. The hole opening of the digging pile shall be provided with a protective net and covered with sandbags. Detonating cords can be added to the surrounding hole for air interval charging, especially in the strongly weathered layer. Record the blasting effect and influence of each time and adjust the drilling and blasting parameters in time according to the stone changes in the hole and the blasting effect.

2) BLASTING EQUIPMENT

Explosives: emulsion explosives, cutting eyes, auxiliary eyes Φ 32x200mm (200g) roll for peripheral eyes Φ 25x200mm (100g) roll.

Detonators: 3, 7, 9 and 12 non-electric millisecond detonators (the time difference is about 25ms), the foot line is 3M long, and the detonator adopts a 7 ~ 10m foot line to terminate the detonating net to the ground point of the pile hole.

Electric detonator: detonator fired immediately after detonation.

Detonating cord: it is used for charging the surrounding eye structure, and the explosive is reduced by 20g per meter.

FINDINGS OF BLASTING

For weathered sandstone and sandstone

In weathered sandstone for 2 m pile diameter holes, explosives should not be used more than 6.6 kg as shown in the table. As the stone is weathered and very soft. After using this amount of explosive in the blast plan shown in figure 1 the following things were found.

1. After the blast the stones were broken into small pieces and no harm was done to the lateral side, the effect of blasting was seen more in the vertical direction as that of the horizontal direction.

2. The same blasting plan and the explosives quantity was used for the slightly less weathered sandstone, then after blasting it was seen that the stone were not broken into smaller pieces, and it was difficult to do the mucking as the stone were of bigger size. So, to avoid that we changed the plan according to table 2 to the same number of holes and then the effect of blasting was much better than that of the 6.6 kg blast. In this blasting also the effect of the blasting was seen in the vertical direction more, in the lateral direction the effect of the blasting was not seen much, and the stone were finely blasted that resulted in breaking down of the stone into the smaller fine pieces.

3. After the successful trial in the Bridge 37 P4 pile number (2, 4, 6) for the weathered and less weathered stone the blasting was carried out in the same manner in other holes having sandstone with same pile diameter and same number of holes as shown in figure 1 and table 1 and table 2 depending upon the nature of sandstone.

4. For other sandstones which are not weathered and less weathered the same pattern as shown in figure 1 and blasting quantity as shown in table 2 was used.

Table 1: Blasting Plan Table for weathered sandstone

Delay No.	No. of holes	Per Hole (KG)	Total
25ms	1	0.6	0.6
50ms	8	0.4	3.2
75ms	14	0.2	2.8
Total	23		6.6

Table 2: Blasting plan for sandstone

Delay No.	No. of holes	Per Hole (KG)	Total
25ms	1	0.8	0.8
50ms	8	0.6	3.2
75ms	14	0.4	5.6
Total	23		9.6

*(In case the number of holes is increased in the 2nd and 3rd row of the blasting plan shown in Figure 1 then the same number of explosives as mentioned in the table should be divided and used.)

For Weathered Slit Stone and Silt Stone

In weathered silt stone and silt stone for 2 m pile diameter holes, explosives should not be used less than 9.6 kg as shown in the table. As the stone is weathered but little hard. After using this number of explosives given in table 3 used in the blast plan shown in figure 1 the following things were found.

1. After the blast (using 9.6 kg) it was seen that the weathered silt stones were not broken in to the smaller pieces and the effect of blast in lateral direction was also seen less as the amount of explosive used was 9.6 kg according to the Table 2, so the amount of explosive was increased on the basis of Table 3 and then the effect of blasting was satisfying as the stones were broken into smaller pieces and the lateral effect of the blasting was good as desired.

2. For silt stone the same amount of explosive was used as of Table 3, but the effect of the blasting was not good, the perpendicular and lateral effect both were not good as desired length was not blasted so we changed the quantity as Table 4, after this the effect of blast was good and as desired.

3. After the successful trial in the Bridge 37 P4 pile number (2, 4, 6) for the weathered silt stone and siltstone the blasting was carried out in same manner in other holes having silt stone with same pile diameter and same number of holes as shown in figure 1 and table 3 and table 4 depending upon the nature of sandstone.

Table 3: Blasting Plan Table for weathered silt stone

Delay No.	No. of holes	Per Hole (KG)	Total
25ms	1	0.6	0.6
50ms	8	0.5	4
75ms	14	0.4	5.6
Total	23		10.2

Table 4: Blasting Plan Table for Silt stone

Delay No.	No. of holes	Per Hole (KG)	Total
25ms	1	0.8	0.8
50ms	8	0.6	4.8
75ms	14	0.5	7
Total	23		12.6

*(In case the number of holes is increased in the 2nd and 3rd row of the blasting plan shown in Figure 1 then the same number of explosives as mentioned in the table should be divided and used.)

For weathered sandstone and sandstone

In weathered sandstone for 2.5 pile diameter holes, explosives should not be used more than 9.8 kg as shown in the table. As the stone is weathered and very soft. After using this amount of explosive in the blast plan shown in figure 2 following things were found.

1. After the blast the stones were broken into small pieces and no harm was done to the lateral side, the effect of blasting was seen more in the vertical direction as that of the horizontal direction.

2. The same blasting plan and the explosives quantity was used for the slightly less weathered sandstone, then after blasting it was seen that the stone were not broken into smaller pieces, and it was difficult to do the mucking as the stone were of bigger size. So, to avoid that we changed the plan according to table 2 to the same number of holes and then the effect of blasting was much better than that of the 9.8 kg blast. In this blasting, the effect of the blasting was seen in the vertical direction more but in the lateral direction the effect of the blasting was not seen much, and the stone were finely blasted that resulted in breaking down of the stone into the smaller fine pieces.

3. After the successful trial in the Bridge 36 P1 pile number (1,2) for the weathered and less weathered stone the blasting was carried out in the same manner in other holes having sandstone with same pile diameter and same number of holes as shown in figure 2 and table 5 and table 6 depending upon the nature of sandstone.

4. For other sandstone which are not weathered and less weathered the same pattern as shown in figure 2 and blasting quantity as shown in table 5 was used.

Table 5: Blasting Plan Table for weathered sandstone

Delay No.	No. of holes	Per Hole (KG)	Total
25ms	4	0.6	2.4
50ms	11	0.4	4.4
75ms	15	0.2	3
Total	30		9.8

Table 6: Blasting plan for sandstone

Delay No.	No. of holes	Per Hole (KG)	Total
25ms	4	0.6	2.4
50ms	11	0.4	4.4
75ms	15	0.3	4.5
Total	30		11.3

*(In case the number of holes is increased in the 2nd and 3rd row of the blasting plan shown in Figure 1 then the same number of explosives as mentioned in the table should be divided and used.)

For Weathered Slit Stone and Silt Stone

In weathered silt stone and silt stone for 2.5 m pile diameter hole, explosives should not be used less than 11.3 kg as shown in the table. As the stone is weathered but little hard. After using this amount of explosive given in table 7 used in the blast plan shown in figure 2 following things were found.

5. After the blast (using 11.3 kg) it was seen that the weathered silt stones were not broken in to the smaller pieces and the effect of blast in lateral direction was also seen less as the amount of explosive used was 11.3 kg according to the Table 2, so the amount of explosive was increased on the basis of Table 7 and then the effect of blasting was satisfying as the stones were broken into smaller pieces and the lateral effect of the blasting was good as desired.

6. For silt stone (less weathered) the same amount of explosive was used as of Table 3 but the effect of the blasting was not good, the perpendicular and lateral effect both were not good as desired length was not blasted so we changed the quantity as Table 8 , after this the effect of blast was good and as desired.

7. After the successful trial in the Bridge 36 P1 pile number (1, 2) for the weathered silt stone and siltstone the blasting was carried out in same manner in other holes having silt stone with same pile diameter and same number of holes as shown in figure 2 and table 7 and table 8 depending upon the nature of sandstone.

Table 7: Blasting Plan Table for weathered silt stone

Delay No.	No. of holes	Per Hole (KG)	Total
25ms	4	0.6	2.4
50ms	11	0.5	5.5
75ms	15	0.4	4.5
Total	30		12.4

Table 8: Blasting Plan Table for Silt stone

Delay No.	No. of holes	Per Hole (KG)	Total
25ms	1	0.8	3.2
50ms	8	0.5	5.5
75ms	14	0.4	6
Total	30		14.7

*(In case if the number of holes is increased in the 2nd and 3rd row of the blasting plan shown in Figure 1 then the same number of explosives as mentioned in the table should be divided and used.)

*(15 kg was also tested for silt stone and the effect was seen satisfying, if 14.7 kg blast was not successful then sometimes 15 kg was also used based on the stone quality.)

*This test was carried out based on the stones found in the bridge 35,36,37,38 topography. In this region, mostly mud stone, sandstone and silt stone are found and very few conglomerate. Conglomerate is same in nature when it is inside but as soon as the blasting is used in this type of stone they break down in the smaller pieces faster than that of the sandstone and the silt stone.

*In some holes there was presence of water, as the ground water table was high, in this kind of hole first holes were drilled and before loading the explosives the water was pumped out of the hole using high power water pump. As soon as the explosives were loaded the water pump was taken out and the hole was filled with water, but the effect of water was not seen on the blasting any time. All the blasting inside the water was successful. So, from this we found out that the effect of water on the blasting is not seen much and it doesn't disturb blasting.

*While loading the explosives the holes need to be closed so while closing the holes sometimes, we use mud, sometimes we use sand. Around 150 to 200 gm of sand or soil was used. It was that when sand was used to close the hole the blast was more effective than when closed with mud or without closing it.

*In the place of using 3 different milliseconds nonelectric detonator when only one nonelectric detonator was used then the effect of blasting was not good but sound of the blasting was louder than that of when we used 3 different non-electric detonators. So, we concluded that blasting with the use of the 3 non-electric detonators was effective.

*When Detcord was used then the effect was good but not as while using the 2 different nonelectric detonators. In place of 25ms ,50ms and 75 ms we can use any other non-electric detonator such as 200ms, 225ms, 250ms according to the availability.

CONCLUSION

The research demonstrates the effectiveness of manual excavation using blasting materials for pile foundations. The findings indicate that careful planning of blasting design and selection of appropriate blasting equipment are crucial for achieving desired blast effects. Manual excavation with blasting proves to be a viable and economical method, particularly in areas with challenging topography and steep slopes. The environmental advantages of manual excavation, such as the avoidance of harmful chemicals, further support the adoption of this method in suitable conditions. The research contributes to the knowledge and understanding of manual excavation techniques for pile foundations, providing valuable insights for future bridge construction projects.

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