DYNAMIC PILE MONITORING REPORT

I-90 INTERCHANGE, WALLACE, IDAHO

U.S. ROUTE 95 KOOTENAI RIVER BRIDGE

BONNERS FERRY, IDAHO

FHWA-DP-66-02

Federal Highway Administration

Office of Highway Operations

Demonstration Projects Division

Washington, D.C.

March 1983

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION

FIELD TRIP REPORT
(See instructions on reverse)

DATE: MAR 22 1983

TO: P. E. Cunningham, Chief
Construction and Maintenance Division
THRU: Gary L. Klinedinst, Chief
Geotechnical and Materials Branch

FROM: Suneel N. Vanikar
Geotechnical Engineer

INCLUSIVE DATES

From March 8, 1983 To March 12, 1983

ITINERARY

Washington, D.C., to Coeur D'Alene, Idaho, and return.

PURPOSE

Dynamic pile testing by the newly acquired field analyzer (computer) at the following bridge sites in Idaho: I-90, West Wallace Interchange area, and U.S. Rt. 95, Bonner's Ferry Bridge over Kootenai River

PRINCIPAL CONTACTS

Messrs. Ron G. Chassie, FHWA Regional Geotechnical Engineer and Robert E. Schamber, FHWA District Engineer.

ACCOMPLISHMENTS OR RESULTS

See attached "Dynamic Pile Test Report"

SUBSEQUENT ACTIONS TAKEN

See attached "Dynamic Pile Test Report"

RECOMMENDATIONS

See attached "Dynamic Pile Test Report"

OTHER PERTINENT ITEMS

Federal Highway Administration
HHO-33:SVanikar:alh:60355:3/22/83
cc:

HRA-010	Mr. Bernard - HHO-40	Reader - HHO-30
HDA-ID(2)	Chron - HHO-33	Vanikar - HHO-33
Ron Chassie - HST-010	Reader - HHO-1	

Suneel N. Vanikar
Geotechnical Engineer

"Dynamic Pile Test Report"

A latest model of field pile analyzer has been acquired for the proposed demonstration project on "Design and Construction of Driven Pile Foundations." The equipment will be used for demonstrations and technical assistance on construction projects.

A request for demonstration and field monitoring of pile driving was received from the Idaho Transportation Department (IDOT) through the FHWA Regional Geotechnical Engineer, Ron Chassie.

Monitoring of pile driving was performed at two bridge sites during the week of March 7, 1983. Brief descriptions of work performed, results, and analysis at the two sites are as follows:

The field work was performed by Mr. H. Clark, Civil Engineering Technician in the Demonstration Projects Division and myself. We were assisted by Dr. Frank Rauche of Goble and Associates - Cleveland, Ohio.

A brief presentation on dynamic analyses of pile driving and the use of equipment was made by Dr. Rauche at the IDOT District Office in Coeur D'Alene on March 9. Engineers from the FHWA Regional and Division offices, IDOT, and the U.S. Forest Service attended the presentation and the field monitoring activities during the week.

Proposed Bridge Site at Wallace

Location and Structure Information

The proposed bridge site is located on I-90 in the West Wallace Interchange area in northern Idaho. The proposed bridge will cross a river and several railroad tracks. The bridge will be a multispan structure requiring 80 to 100 footings. The bridge foundations have not been designed yet.

Subsurface Conditions

Dense sandy gravel and boulders overlie bedrock at the boring locations. The depth of overburden over the rock is 35 to 40 feet. The subsurface conditions at most support locations (except for those in river crossing area) seem suitable for spread footing foundations but the IDOT desires to design and construct pile foundations for all the substructure units.

Test Pile Program

A test pile program during this stage of design was proposed by the IDOT. It was decided to drive four test H-piles at the site, monitor the driving by using the pile analyzer and then extract the piles. The purpose for the test pile program was as follows:

1. To determine whether HP 14x102 piles with "APF Hardbite steel points" can be driven to rock.
2. To determine pile lengths required to obtain design load capacity of 135 tons each.
3. To determine the ultimate load capacity of piles.
4. To assess the driving stresses generated in the piles.
5. To observe the damage to the piles after pulling them out.

Pile Data: HP 14x102 with "APF Hardbite steel points."
length - 40 feet
Maximum design load - 135 tons
Maximum design stress in the pile material - 9,000 p.s.i.

Hammer Data: Kobelco K-20 supplied by L.B. Foster, Inc.
"Fosterloin" Hammer Cushion.

Description of Field Monitoring Activities

March 9, 1983 - During the morning (after a brief presentation at the District Office) the required holes for the attachment of strain gages and accelerometers were drilled on four piles. Fuses on the tape recorder and oscilloscope were damaged due to a faulty generator which resulted in the tape recorder not being used on this project.

The pile at location TH-8 was driven in the morning without any difficulty. The pile reached a practical refusal on bedrock at 37'-9" below ground surface (16 blows per inch). Pile at location TH-6 was driven and monitored in the afternoon. Driving was stopped when the pile tip reached a depth of 35'-2" (13 blows per inch).

In addition to the data recorded and analyzed by the pile analyzer, records of blow count and hammer stroke were recorded by using a "Saximeter" and also by the traditional method of recording blow counts.

March 10, 1983 - Pile at location TH-4 was driven in the morning to a depth of 38'-4" but did not reach refusal (3 blows per inch). Pile at location TH-2 was driven the same morning to a depth of 38'-5" and reached practical refusal (12 blows per inch).

In the afternoon, a pile at TH-8 was extracted by using a vibratory extractor. Damage to the pile tip was noted from a large cobble which had wedged between the flanges.

Note: Piles at locations TH-6, TH-4 and TH-2 were pulled out on March 11, 1983 when we were monitoring pile driving at the Bonner's Ferry Bridge. Mr. Ron Chassie who observed the extracted piles on that day told us that piles at locations TH-6 and TH-2 were substantially damaged at the tip. We do not have the photographs of the damaged piles at this time.

Discussion of Results

Pile at location TH-8: Table 1 shows a summary of the results provided by the analyzer and the transfer efficiency computations for the pile at location TH-8. It shows that maximum compressive stresses generated in the pile did not exceed 33 k.s.i. (allowable driving stress is 1.1 x fy = 1.1 x 36 = 39.6 k.s.i.). The hammer stroke was measured by using Saximeter. The transfer efficiencies determined by using measured transferred energy in the pile were between 39 percent and 46 percent which shows that the hammer performed very well. An ultimate static load capacity (with a damping factor of 0.15) of 450 tons was predicted for the pile. This pile was damaged in the pile tip area.

Pile at location TH-6:

Table 2 shows a summary of results provided by the analyzer and transfer efficiency computations for the pile at location TH-6. It shows that maximum compressive stresses generated in pile did not exceed 29.7 k.s.i.

The Saximeter records were not kept for this pile so the transfer efficiency computations are based on the rated hammer energy of 51.519 ft kips at 9.35 ft. stroke.

An ultimate static load capacity (with a damping factor J = 0.15) of 445 tons was predicted for the pile. This pile was substantially damaged in the tip area. Damage was indicated on the force trace on the oscilloscope during driving.

Pile at location TH-4

Table 3 shows a summary of results provided by the analyzer and transfer energy computations for pile at location TH-4. This pile did not reach the refusal on bedrock.

The maximum compressive stress generated in the pile was 23.8 k.s.i. The transfer efficiencies in the range of 36 percent to 41 percent indicate that the hammer was performing well. This pile was driven slanted.

An ultimate static load capacity (J = 0.15) of only 125 tons was predicted for the pile which allows only 63 tons design load (F.S. of 2). The pile was not damaged.

Pile at TH-2

Table 4 shows a summary of results provided by the analyzer and transfer energy computations for the pile at location TH-2. It shows that the maximum compressive stress generated during driving was 24.3 k.s.i. The pile was driven slanted and lower transfer efficiencies of 31 percent to 42 percent were determined.

An ultimate static load capacity of 350 tons (J = 0.15) is estimated. A parametric study of the effect of different J values on ultimate capacity shows that even with J = 0.38 (very high or this type of soil) the pile has ultimate capacity of 338 tons. This pile was damaged substantially during driving. The damage was observed after the pile was extracted.

Conclusions and Recommendations

1. The dynamic monitoring equipment performed well. Capacity preditions and pile force measurements were consistent and reasonable. Pile damage was detected during driving for one pile.

2. Use pile foundations only in those areas where foundations would be susceptible to scour. All other foundations should be spread footings. The fact that all the three piles which attained refusal and high capacities were damaged during driving requires a serious consideration of spread footing foundation in lieu of pile foundations.

3. The hammer (Kobe K-25) and cushioning (Fosterloin) used for HP 14x 102 seem to be well matched to the pile and soil type. The hammer performed very well.

4. The results of the wave equation analyses performed by IDOT should be compared with the data and analyses provided in this report.

Bonner's Ferry Bridge Site

Location and Structure Information

This bridge is being constructed on U.S. Rt. 95 over Kooteni River in the town of Bonner's Ferry in northern Idaho. The bridge is a multispan structure with most piers and one abutment supported on pile foundations.

Subsurface Conditions

The tested pipe pile is located at pier 6. Boring DH-8 at pier 6 shows 18' of medium dense gravelly sand underlain by dense sandy gravel.

Pile Data

The test pile at pier 6 was a steel pipe pile 16" o.d. and 3/8" wall thickness with 1" thick closure plate. The pipe was battered. Total pile length was 100 feet. Pile driving was monitored from pile penetration at 21 feet below river bed to the end of driving with pile tip at 54 feet below river bed. Piles are designed for a maximum static design load of 90 tons.

Hammer Data - Delmag D-30.

Purposes for Dynamic Monitoring

1. To determine pile capacity.

2. To determine driving stresses in the pile.

3. To gain experience and demonstrate the use of equipment.

Discussion of Results

Table 5 shows a summary of the results provided by the analyzer and transfer efficiency computations for the batter pile at pier 6.

The maximum dynamic compressive stresses induced in the pile were well within the limit (the limitation is 1.1 x fy = 1.1 x 36 = 39.6 k.s.i.).

The transfer efficiencies were between 30 and 40 percent which indicates a good pile hammer performance.

An ultimate static load capacity (with a damping factor of approximately 0.20) of 180 tons was predicted for the pile. The maximum design load used in the design was 90 tons. This provides a factor of safety of 2 which is reasonable.

All the components of dynamic testing equipment performed well. The data was recorded on a tape for further analysis.

TABLE 1 - PILE AT TH-8

(I-90, Wallace, Idaho)

DEPTH*	BLOW COUNT PER INCH	RSTC with J=0.15 KIPS	F. Max. KIPS	MAX. COMP. STRESS K.S.I.	MAX. TRANSFER ENERGY FT. KIPS	STROKE FT.	HAMMER ENERGY RAM WT. X STROKE FT. KIPS	TRANSFER EFFICIENCY TRANSFER ENERGY / ACTUAL HAMMER ENERGY	TRANSFER EFFICIENCY (transfer energy / 51.519)	REMARKS
25'-0"	3	240	700	23.3	12.5	5.6	30.86	40.5%	24%	Max. stress figure is the max. computed from either FMAX or RSTC.
30'-0"	2.3	290	740	24.7	13.0	5.3	29.20	44.5%	25%	Max. rated energy for KOBE K-25 hammer.
35'-0"	2.8	375	830	27.7	14.8	5.8	31.96	46.30%	29%	51,519 ft. lbs at 9.35 ft. stroke (51.519 ft. KIPS)
36'-0"	3.5	560	890	29.7	15.7	6.4	35.26	44.53%	30%	Ram wt-5,510 lbs.
37'-0"	10	850	910	30.3	17.0	7.0	38.57	44.08%	33%	
37'-6"	12	920	900	30.7	16.0	7.0	38.57	41.48%	31%	Stroke measured by "Saximeter"
37'-9"	16	990	874	33.0	16.0	7.0	38.57	41 48	31%	
37'-6"	12	874	855	29.1	15.2	7.0	38.57	39.41%	30%	Adjusted capacity energy and max. force by -5% because of non proportionality of F&V Traces on oscilloscope
37'-9"	16	941	830	31.4	15.2	7.0	38.57	41.48%	30%	

Ultimate Static Load Capacity =RSTC= 900 KIPS
(Damping Factor J=0.15) = 450 Tons

*Distance from the ground surface to pile tip.

RSTC = Ultimate Static Resistance.

FMAX = Maximum measured force in pile at the transducer location.

TABLE 2 - PILE AT TH-6

(I-90, Wallace, Idaho)

DEPTH*	BLOW COUNT PER INCH	RSTC with J=0.15 KIPS	F. Max. KIPS	MAX. COMP. STRESS K.S.I.	MAX. TRANSFER ENERGY FT. KIPS	STROKE FT.	HAMMER ENERGY RAM WT. X STROKE FT. KIPS	TRANSFER EFFICIENCY TRANSFER ENERGY / ACTUAL HAMMER ENERGY	TRANSFER EFFICIENCY (transfer energy) / 51.519	REMARKS
25'-0"	2	190	600	20.0	11.0	N/A	---	---	21%	Max. comp. stress is the max. computed from either FMAX or RSTC.
30'-0"	2.5	320	700	23.3	12.5	N/A	---	---	24%	
33'-0"	4.5	650	775	25.8	14.7	N/A	---	---	29%	Max. rated energy for KOBE K-25 is 51.519 ft KIPS at 9.35 ft. stroke
35'-0"	9.0	890	840	29.7	17.0	N/A	---	---	33%	RAM wt.-5,510 lbs
35'-2"	13.0	890	860	29.7	16.7	N/A	---	---	32%	Stroke measured by "Saximeter"

Ultimate Static Load Capacity = RSTC = 890 KIPS
(J = 0.15) = 445 Tons

*Distance from the ground surface to pile tip.

RSTC = Ultimate Static Resistance.

FMAX = Maximum measured force in pile at the transducer location.

TABLE 3 - PILE AT TH-4

(I-90, Wallace, Idaho)

DEPTH*	BLOW COUNT PER INCH	RSTC with J=0.15 KIPS	F. Max. KIPS	MAX. COMP. STRESS K.S.I.	MAX. TRANSFER ENERGY FT. KIPS	STROKE FT.	HAMMER ENERGY RAM WT. X STROKE FT. KIPS	TRANSFER EFFICIENCY TRANSFER ENERGY / ACTUAL HAMMER ENERGY	TRANSFER EFFICIENCY (transfer energy / 51.519)	REMARKS
25'-0"	1.8	133	620	20.7	10.2	4.9	27.00	37.8%	19.8%	Max. comp. stress figure is either FMAX or RSTC.
30'-0"	2.2	190	650	21.7	10.5	4.9	27.00	38.9%	20.0%	Max. rated energy for KOBE K-25 hammer is 51.519 ft.KIPS at 9.35' stroke.
35'-0"	3.1	340	730	24.3	12.8	5.7	31.41	40.8%	24.8%	
37'-0"	2.4	305	715	23.8	11.5	5.8	31.96	36.0%	22.3%	
38'-4"	2.7	252	666	22.2	10.5	N/A	---	---	20.4%	Stroke measured by "Saximeter" Ram wt.-5.510 lbs The pile was driven slanted

Ultimate Static Load Capacity = RSTC = 250 KIPS
(J=0.15) = 125 Tons

*Distance from the ground surface to pile tip.

RSTC = Ultimate Static Resistance.

FMAX = Maximum measured force in pile at the transducer location.

TABLE 4 - PILE AT TH-2
(I-90, Wallace, Idaho)

DEPTH*	BLOW COUNT PER INCH	RSTC with J=0.15 KIPS	F. Max. KIPS	MAX. COMP. STRESS K.S.I.	MAX. TRANSFER ENERGY FT. KIPS	STROKE FT.	HAMMER ENERGY RAM WT. X STROKE FT. KIPS	TRANSFER EFFICIENCY TRANSFER ENERGY / ACTUAL HAMMER ENERGY	TRANSFER EFFICIENCY (transfer energy) / 51.519	REMARKS
25'-0"	2.3	225	660	22.0	12.8	5.5	30.31	42.2%	25%	Max. comp. stress figure is the max. computed figure from FMAX or RSTC
32'-0"	4.2	400	670	22.3	10.6	5.6	30.86	34.3%	20.5%	
35'0"	4.5	410	670	22.3	11.0	5.9	32.51	33.8%	21.4%	Max rated energy for KOBE K-25 hammer is 51.519 ft.KIPS at 9.35 stroke
38'-5"	12	705	730	24.3	14.2	7.2	39.67	35.8%	27.6%	Ram wt-5,510 lbs; stroke measured by "Saximeter"

Ultimate Static Load Capacity = RSTC = 700 KIPS
(J = 0.15) = 350 Tons

DEPTH*	BLOW COUNT PER INCH	RSTC KIPS	F. Max. KIPS	MAX. COMP. STRESS K.S.I.	MAX. TRANSFER ENERGY FT. KIPS	STROKE FT.	HAMMER ENERGY FT. KIPS	TRANSFER EFFICIENCY	TRANSFER EFFICIENCY (/51.519)	REMARKS
38'-5"	12	676 (J=0.38)	665	22.5	12.5	7.2	39.67	31.5%	27.6%	The pile was driven slanted
38'-5"	12	841 (J=0.0)	665	28.0	12.5	7.2	39.67	31.5%	27.6%	

*Distance from the ground surface to pile tip.

RSTC = Ultimate Static Resistance.

FMAX = Maximum measured force in pile at the transducer location.

TABLE 5 - PILE AT PIER 6
(U.S. Route 95, Bonner's Ferry Bridge, Idaho)

Pile Tip depth below River Bed	BLOW COUNT PER INCH	RSTC with J=0.2 KIPS	F. Max. KIPS	MAX. COMP. STRESS K.S.I.	MAX. TRANSFER ENERGY FT. KIPS	STROKE FT.	HAMMER ENERGY RAM WT. X STROKE FT. KIPS	TRANSFER EFFICIENCY TRANSFER ENERGY / ACTUAL HAMMER ENERGY	TRANSFER EFFICIENCY (transfer energy) / 54.3	REMARKS
25'-0"	2.0	157	440	23.9	15.5	6.3	41.58	37.3%	28.5%	Max. stress is the max. computed from either FMAX or RSTC
35'-0"	1.6	236	425	23.1	16.3	6.4	42.24	38.6%	30.0%	Max rated energy for Delmag D-30 hammer is 54.3 FT.KIPS
45'-0"	2.3	262	457	24.8	13.6	6.7	44.22	30.8%	25.0%	
45'-0"	2.3	356 (J=0)	457	24.8	13.6	6.7	44.22	30.8%	25.0%	wt. of ram-6.6 KIPS Stroke measured by "Saximeter"
54'-0"	3.4	360	511	27.8	18.5	6.9	45.54	40.6%	34.1%	

Ultimate Static Load Capacity RSTC = 360 KIPS
(Damping Factor J = 0.20) = 180 Tons

*Distance from the ground surface to pile tip.

RSTC = Ultimate Static Resistance.

FMAX = Maximum measured force in pile at the transducer location.