PDHonline Course G420 (3 PDH)

Basics on Forensic Engineering - Part III

Instructor: Ruben A. Gomez, PE

2020

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Basics on Forensic Engineering
Part III

Ruben A. Gomez, P.E.

1.0 Introduction

Despite the perceptions and misconceptions of the misinformed detractors of forensic engineering who see that practice as a group of opportunists who are merely trying to take advantage of other engineers' misfortunes. Granted, there have been engineers, perhaps with reasons of their own, who willingly have testified in court against some of their colleagues. However, that mere fact does not make them forensic engineers, nor is such an activity what the specialty of forensic engineering is about. Consequently, we invite those detractors to read all of the five parts of this course to realize how wrong they are in their poor assessment of the facts.

The forensic engineer is a practitioner who can be of immense help and assistance to not only the personnel of an insurance company and to a litigating attorney, but to the plaintiff's case as well. Whether it is in the area of property damage (comprising earthquake, hurricane, tornado, lightning or hail), fire damage and/or fraud, car collision, slip & fall, trip & fall, or in the ultimate role of the expert witness. Those are areas which generally require vast amounts of accumulated knowledge and where an experience engineer can shine on his merits, be useful and earn a well paid fee while doing what he likes best.

Since the forensic engineer gets paid for what he knows, he should always be ready to show his expertise without arrogance or conceit. The secret of success, amongst other things, is preparation and preparedness, and since he knows from the start the extent of the case ahead of time, for it is part of his written assignment, then he should take a few hours to read all he can, especially on the material available about similar cases. For instance, if he has a case about hurricane damage, he should retrieve all information available on that particular event: name, category, known and anticipated path, (rotational) wind speed, rate of motion, history of recent damage, configuration of the storm (they are usually asymmetric), etc. All such information is available on the Internet from sites such as: the National Hurricane Center (NHC) or the National Oceanic and Atmospheric Administration (NOAA). In a nutshell, he should take the time to get informed and make sure he knows more about the event than anyone else present at the site.

He should also have at hand a check list containing all those items that are important in the discharge of his duties, such as:

a. business cards
b. a working pen and a writing pad
c. a good camera

d. tape measure
e. flash or flood light
f. compass
g. carpenter's level
h. laser level
j. magnifying glass
l. telephone
m. stiletto (foil)
n. mechanic's tools
p. carpenter's hammer
q. sledge hammer
r. chisel
s. pocket knife
t. folding ladder
u. pair of boots
v. raincoat
w. shovel
x. first aid kit
y. plenty of drinking water

Had to stop there because we ran out of letters in the alphabet, but do not hesitate to bring whatever else you may think of, it is better to have more than what you need than the alternative.

Be ready to climb on roofs and crawl in attics and crawl spaces, if you are too old, too finicky, claustrophobic, or have low back ailments, bring along a younger helper or a trainee who can do the climbing and crawling, and occasionally hold the other end of the measuring tape for you.

Before you attempt to enter an attic, make sure you understand this clearly: to do it safely, you need to locate the first rafter or truss bottom chord where you can steadily stand (or squat) on with your left foot, while with your other foot you try over the insulation until you find the next rafter (likely two feet ahead) and you continue progressing one rafter at the time towards your target. Those rafters or truss bottom chords are the only places where you may stand on, the other places in between only have drywall or sheetrock, if you make the mistake of stepping on them you will fall down to the lower level. It may sound as this should be obvious to all of us, however, the author has seen many colleague engineers who have done exactly that, and by the way, you will be responsible for the damages and the embarrassment. If you have insurance coverage, and it has been herein recommended you do, notify them about the incident. At that point two things will happen, you will be responsible for the deductible, and very likely, on the next policy renewal your premium will increase. Therefore, please pay attention and avoid the entire situation.

Your camera is the most important tool at your disposal, for it can "see" things that you could have missed or could not have seen otherwise. Take good photographs by always keeping in mind to look for the right angle and where the light is coming from. More

often than not, in an attic there is no lighting and you may have to depend on your flashlight for illumination, so your camera will become even more important to you by uncovering hidden or unnoticed details you would have missed otherwise.

Once you have the pictures you took at the site and have them ready to be used, whether you picked them up from the photo development shop or you uploaded the set to your computer, take the time to study them to the very minute detail. First, group them by content and second, by the quality of image. Eliminate those which are over-exposed to light, irrelevant, fragmented, out-of-focus or incomplete. Those that have survived your scrutiny are the ones for the report. Next, you spread them on your desk in front of you and place them in the order and sequence that are best for the flow and continuity of the narrative you already have in mind. You are ready now to start the writing process; your pictures will tell you what to say in a way that is comprehensive to the users of your report.

Of all things, you should also be prepared for these: your client at the insurance company will not only want to know a detailed account of the damage you saw at the site, but also why and how it happened, and as important, he may also want you to distinguish the damage sustained by an "act of God" or whatever the event that took you up there, from the "pre-existing" damage which was there from before. You will find that to be very important for the insurer to know. We will cover later, in another part of this series ahead, how to easily differentiate between *fresh and current* damages from *pre-existing* damages.

2.0 THE ROLE OF THE ADJUSTOR

The Adjustor (or Adjuster) plays an important role in the claim department of an insurance company, he examines and brakes down the claim into comprehensive categories and items, then he assesses and quantifies those items within the limits of the claim and places a dollar value on such items, which summation gives the total amount proposed for payment as a settlement of the insurance claim.

He (or she) is also the "first line of defense" in detecting the possibility of fraud, as it is an ever present ingredient in any claim. Although most claims are in principle justified and legitimate, however, they could also well be inflated, exaggerated or sometimes even borderline fraudulent.

Needless to say that the forensic engineer should do his work having in mind the function of the adjustor and facilitate his report in order to make it comprehensible to the last member down the line through the long list of users. Therefore, the report language, although being reasonably acceptable to other engineers, should also be simple enough to be understood by the layman.

When it comes to the relationship between the forensic engineer and the insurance company, the former needs to use his experience and knowledge to make

determinations of fact and render his opinions and conclusions to the best of his abilities, and although his job is not to consider or determine the presence of fraud, he should be well aware of the adjustor's mission and have a good understanding of which the indicators of fraud are.

According to the National Insurance Crime Bureau, the indicators of fraud are:

a. Insured is overly pushy for a fast settlement,
b. he seems to be unusually familiar with the insurance terminology and the claim settlement process,
c. he handles all transactions in person, as if he was avoiding using the U.S. Mail,
d. he would even be willing to accept a lesser settlement rather than having to document the losses.
e. Insured has been recently divorced or is separated from his (her) spouse,
f. none of his family members were present during or at the scene of the accident that triggered the claim,
g. loss took place immediately after the policy took effect, or immediately before it lapsed.
h. Loss is incompatible with the insured's residence, occupation or income.
j. In case of a seasonal business, loss occurred at the end of season or during the off-season period.

Again, it is not the forensic engineer's job to make the determination of fraud, but it would be helpful to make mention of any noticeable evidence. Whether it is done within or without the report is a matter of personal judgment.

3.0 CASE HISTORY

On this Part III of the Forensic Engineering series, we are presenting a case of alleged property damage due to vibration waves generated by certain construction equipment working on a nearby road construction project.

Before we enter into the details of the case, it is important for the reader to know that since his humble beginnings, man has shown a certain degree of sensitivity towards vibrations, first as result of the frequent earthquakes whether as consequence of tectonic adjustments of the planet crust or caused by volcanic eruptions, and in more recent times by the advent of mechanical equipment created as part of the modern day industrial revolution.

Several studies on human awareness conducted during the last 80 years have shown that people are normally very aware of vibrations around them. Sometimes those vibrations are even one-hundred times smaller than those which could pose danger to their possessions and houses. Furthermore, when construction equipment becomes noticeable in a residential neighborhood, particularly rollers and pile hammers, people become alert and concerned about their properties and always expect the worst of all

possible scenarios.

In the author's recollection, there is a relevant case worth mentioning. By the mid 1990's M.S. Corporation, a large and experienced road builder from New Jersey was awarded several contracts for road building within the Dade County area in South Florida. That company had in mind something uncommon for the times, although retaining their Workmen Compensation insurance coverage, considering the fast escalating insurance premiums, with the blessings from Florida DOT, the upper management decided to make an experiment by becoming self-insured in the area of public liability. They created their own Department of Risk Management with separate divisions of Work Safety and Liability Prevention.

This author was retained as a consultant and was asked to prepare and institute a liability prevention plan. The pilot project was the widening of an existing three-mile NE street in the area of North Miami. A two-lane asphalt road to be widened to four lanes within an 80 ft. wide right-of-way. The scope of the work included repaving the old asphalt surface, adding two new lanes, placing sidewalks and gutters on both sides of the road, paint striping and signalization and the construction of an overpass as well.

By the above described scope of work it can be deducted that the operation included the two most feared pieces of equipment when it comes to the possibility of vibration damage: vibratory rollers and pile drivers. As a designated sensitive area we established a 200 ft. wide corridor along the centerline of the existing road and identified an inventory consisting of 312 structures. In a course of two months we were able to prepare a condition assessment and content inventories of every structure within the designated sensitive area. Every crack, each case of fallen stucco and every detectable damage was examined, recorded, accounted for and photographed accordingly. Contents were documented and photographed as well. A file folder was prepared on every property within the designated 3.2 million square feet area and placed in a vault for safekeeping. During pile driving and compaction activity days we kept at the site an accelerometer and a seismograph to monitor all vibrations, measured Energy Ratios and kept them within acceptable range by maintaining constant communication with the equipment operators.

As expected, at the end of the project there were a large number of claims, grievances and complaints. We inventoried the sensitive area again and compared our new findings against the results of the first survey and were able to dismiss as unfounded over 90% of those claims. In the end we conceded on 16 (out of 286) legitimate claims of actual documented damage of which only 3 masonry structures appeared with new cracks, all the rest were enlargements of the old floor and/or wall cracks. In one of the houses the housewife had two dozen very delicate wine glasses of which one-third were cracked and had to be paid for. The total dollar amount spent on repairs and restitutions was $89,400.

This author had the opportunity to confirm the validity of the concepts predicated for years by the Safety Engineering Department of Liberty Mutual Insurance Company. Their charts showed that while human awareness to vibrations started at low Energy

Ratio levels of less than 0.001 and awareness grew into alarm at about the 0.1 level, the danger to common structures did not get any significant until such released energy bordered on 3.0 and became really dangerous at the 5.0 level. From our end, we witnessed the vibratory roller passing a dozen times by an existing masonry corner house just 15 ft. away from the path of the machine with a calculated Energy-Ratio of 0.12 and in spite of all the (low frequency) vibrations shaking the house, it escaped unscathed and crack free, while others at twice the distance sustained crack enlargements; the usual paradox of field observations.

Now, with no more ado, let us go into the case at hand:

PRELIMINARY REPORT ON

ALLEGED DAMAGES TO A RESIDENTIAL WATERWELL AT
531 N.E. 37th STREET
POMPANO BEACH, FLORIDA 33064

OWNED BY

STEVEN & SUSAN LAWTEY

FOR

Ms. MARY JANE DAVIDSON, CLAIM REPRESENTATIVE
3230 WEST COMMERCIAL BOULEVARD
FORT LAUDERDALE, FLORIDA 33309

FILE CASE #9367

DATE OF LOSS: 06-15-1993
DATE OF REPORT: 07-30-1993

TABLE OF CONTENTS

1.0 ASSIGNMENT

1.1 The homeowners (and claimants) allege that during construction of the N.E. 38th Street to the North side of their property, ground vibrations were originated as result of the compaction work performed by Pavex Corporation (the insured). Those vibrations were generated with enough intensity so as to induce the collapse and consequently disrupt the operation of their deep water well, the only source of potable water for their house.

1.2 The engineer is directed to inspect the site conditions and determine if the alleged well collapse is related to the Insured's work.

1.3 Please prepare a written report and submit it to the Claim Representative.

2.0 PARTICIPATING PERSONNEL

2.1 Present at the site during our inspection were:

2.1.1 Mrs. Susan Lawtey, Homeowner
531 N.E. 37th Street
Pompano Beach, Florida 33064

2.1.2 Ms. Mary Jane Davidson, Claim Rep.
3230 West Commercial Boulevard
Fort Lauderdale, Florida 33309

2.1.3 Mr. Ruben A. Gomez, P.E.
1216 Oakfield Drive
Brandon, Florida 33511

2.2 Persons interviewed at their places of work:

2.2.1 Mr. Phong Li, Environmental Engineer
Environmental Engineering Division
Broward County Public Health Department
2421 S.W. 6th Avenue
Fort Lauderdale, Florida 33315

2.2.2 Ms. Terry Cordell, Supervisor
Division of Public Wells
Broward County Department of Natural Resources
2995 Old Dixie Highway
Fort Lauderdale, Florida 33394

2.3 Persons Interviewed over the phone:

2.3.1 Mr. John E. Carroll
Pavex Corporation
2501 N.W. 48th Street
Pompano Beach, Florida 33073

2.3.2 Mr. Edward Santos, Owner
Santos Mechanical Services
5151 N.W. 76th Place
Pompano Beach, Florida 33071

Author's Note:
Some of the names have been changed to protect their privacy.

3.0 OBSERVATIONS

3.1 Examination of the allegedly damaged water well took place at 2:00 PM on Friday July 23, 1993.

3.2 The Claimant's property consists of a single story duplex located as shown on the enclosed Exhibits "A" and "B", as well as on Picture #1. The property was purchased in 1986 and carries a 1960's vintage.

3.3 Two water wells serve the property, as seen on the above referred exhibits. A deep water well is being used for drinking water supply, and a shallow well is used for irrigation purposes. According to the Claimant's statements, the deep water well has collapsed and the shallow well is still working satisfactorily.

3.4 Our examination of the system resulted in the following observations:

3.4.1 A 3/4 H.P., 115V, 6.2A pump serves the deep well.

3.4.2 A short garden hose was used for the purpose of priming the pump and bypass the deep well, as can be seen on enclosed Pictures #4 and #5.

3.4.3 A storage system in the form of a hydropneumatic tank was observed. Pressure switch was set at 40/60 psi.

3.4.4 Both, storage tank and pump seemed to be of recent installation.

3.5 As part of our examination, we primed and started the pump. In spite of a large amount of compressed air trapped in the system, the pump was able to fill up the storage tank to the required turn-off pressure. After a few on/off cycles, the system got overpumped with the resulting loss of priming. Conclusively, the well did not have an adequate yield, and a diminishing yield is generally related to well partial occlusion.

3.0 OBSERVATIONS (continued)

3.6 On the North side of the Claimant's property, a single family housing development was observed to be in its initial phase of construction. Picture #2 shows a partial view of the area under development, as well as the location of recently built N.E. 38th St. According to our field measurements, the nearest possible position of the vibratory rollers, with respect to the subject well location, should have been approximately 160 ft. as can be graphically seen on enclosed Exhibits "B" and "C".

3.7 Soil characteristics, as determined by visual inspection and through examination of soil borings available at the adjacent housing project, can be designated as silica sand with limestone and shell fragments, and traces of roots and organic matter, mainly on the shallow stratum. For the purposes of ground wave propagation, it may be classified simply as "sandy soil".

3.8 According to established national standards in the field of ground vibration studies, ground motions have been classified by their Energy-Ratio values, which in simple terms measures the intensity of released energy in relation to the damage it can cause to conventional construction. It is normally accepted that Energy-Ratio values of 1.10 or less are harmless to standard construction (see Exhibits "D" and "E").

3.9 Based on field vibration readings from digital seismographs, as monitored by Vibration Energy Services, Inc. on similar circumstances (same soil type/same vibratory rollers). The resulting Energy-Ratio values, as determined by us, were considerably lower than the allowable limits.

3.10 In addition to the empirical and mathematical models examined, several county government technicians and private well drillers were interviewed, and the following data was gathered:

3.10.1 Private wells inventory and files were traced back to 1982. No information regarding the subject well was found on the available files, as an indication that the drilling of such well predated 1982.

3.0 OBSERVATIONS (continued)

3.10.2 Required minimum depth for drinking water wells ranges from 50 to 60 ft. depending on water quality. No maximum depth.

3.10.3 Normal well life expectancy is 20 years. Galvanized steel or black iron casings are particularly sensitive to corrosive waters, their pollutants and suspended chemicals, such as: carbon dioxide, hydrogen sulphide, sodium sulphate and magnesium sulphate. Pipe walls would corrode, followed by collapse and then allowing intrusion of solid matter, with the resulting reduction in well yield and consequently sponsoring overpumping, as in the subject case.

3.10.4 Wells with 2 in. casings (and larger) could be saved and rehabilitated by dropping a smaller pipe inside, as replacement for the failed suction line.

3.10.5 Amps Aquifer (see Par. 2.3.2) offers the service of a full examination of the casing interior wall. A miniature video camera is introduced into the well to accomplish this purpose. Results are provided in a video cassette. The cost for this service runs for approximately $1,200.

4.0 CONCLUSIONS

4.1 Taking into account the extremely low Energy-Ratio delivered at the deep well location by the induced ground vibrations. Also taking further into account the age of said well, any collapse or occlusion of the well casing could hardly be attributed to the Insured's road construction operation. Rather, the wear and tear and the natural aging process are to be blamed for the well's diminishing yield.

5.0 EXHIBITS

5.1 Exhibit "A" shows a scaled site plan with the location and orientation of the Claimant's property. It also shows the relative location of the deep well, subject of this report.

5.2 Exhibit "B" depicts Claimant's property relative to the location of the new road.

5.3 Exhibit "C" is a cross-section extending from N.E. 37th St. to N.E. 38th Street. It shows location of the subject well in relation with the source of vibration.

5.4 Exhibit "D" is an Acceleration vs. Frequency Chart. Energy-Ratio values are computed based on the traditional Kinetic Energy formula:

$$ER = a^2/f^2$$

Where:

a = acceleration (ft/sec/sec), and
f = frequency (cycles/sec).

5.5 Exhibit "E" provides clarification and interpretation on the features and parameters shown on Exhibit "D".

JOB 9367

SHEET NO. OF

CALCULATED BY DATE

CHECKED BY DATE

SCALE 1" = 20'

RUBEN A. GOMEZ, P.E.
STRUCTURAL ENGINEER

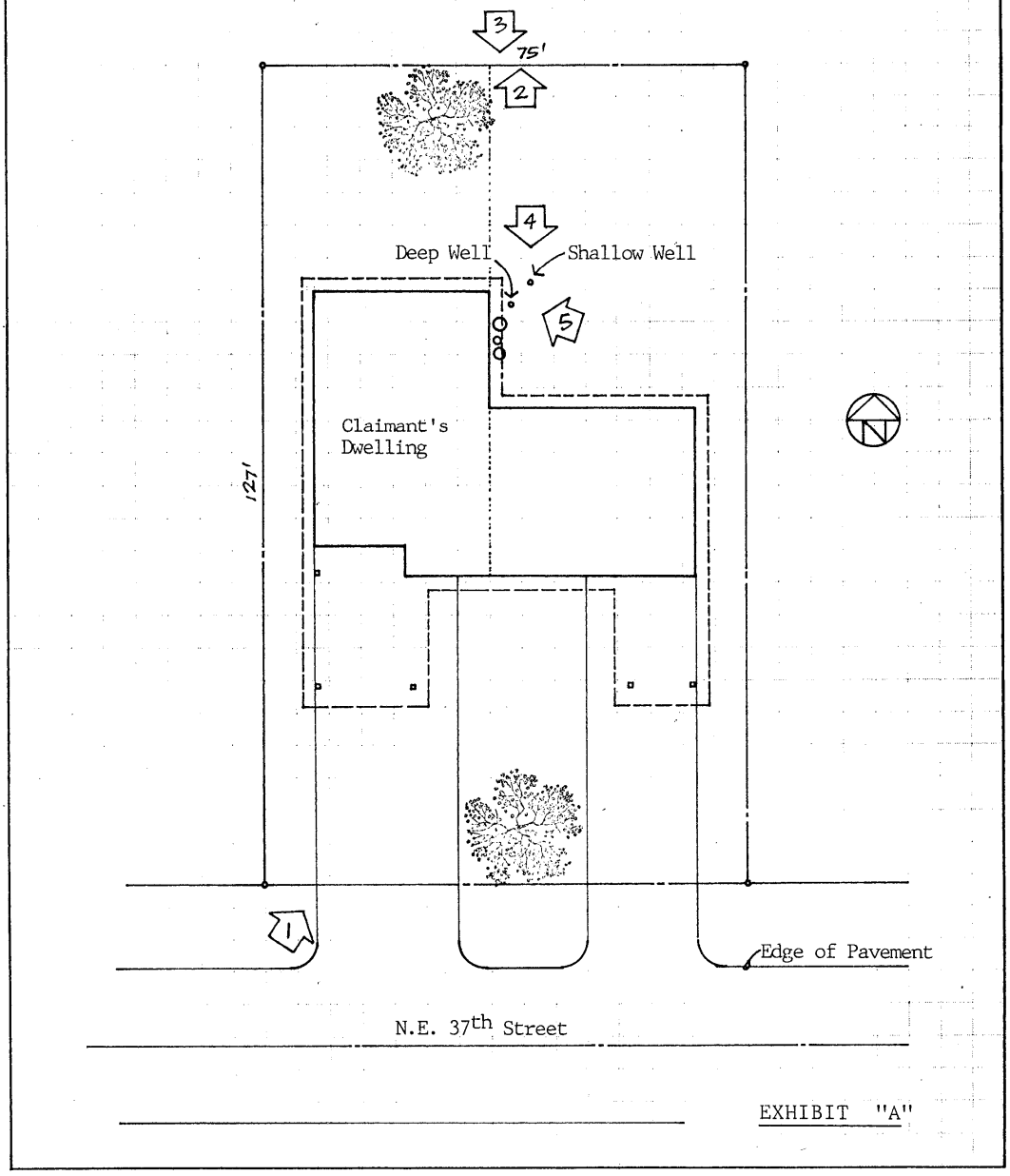
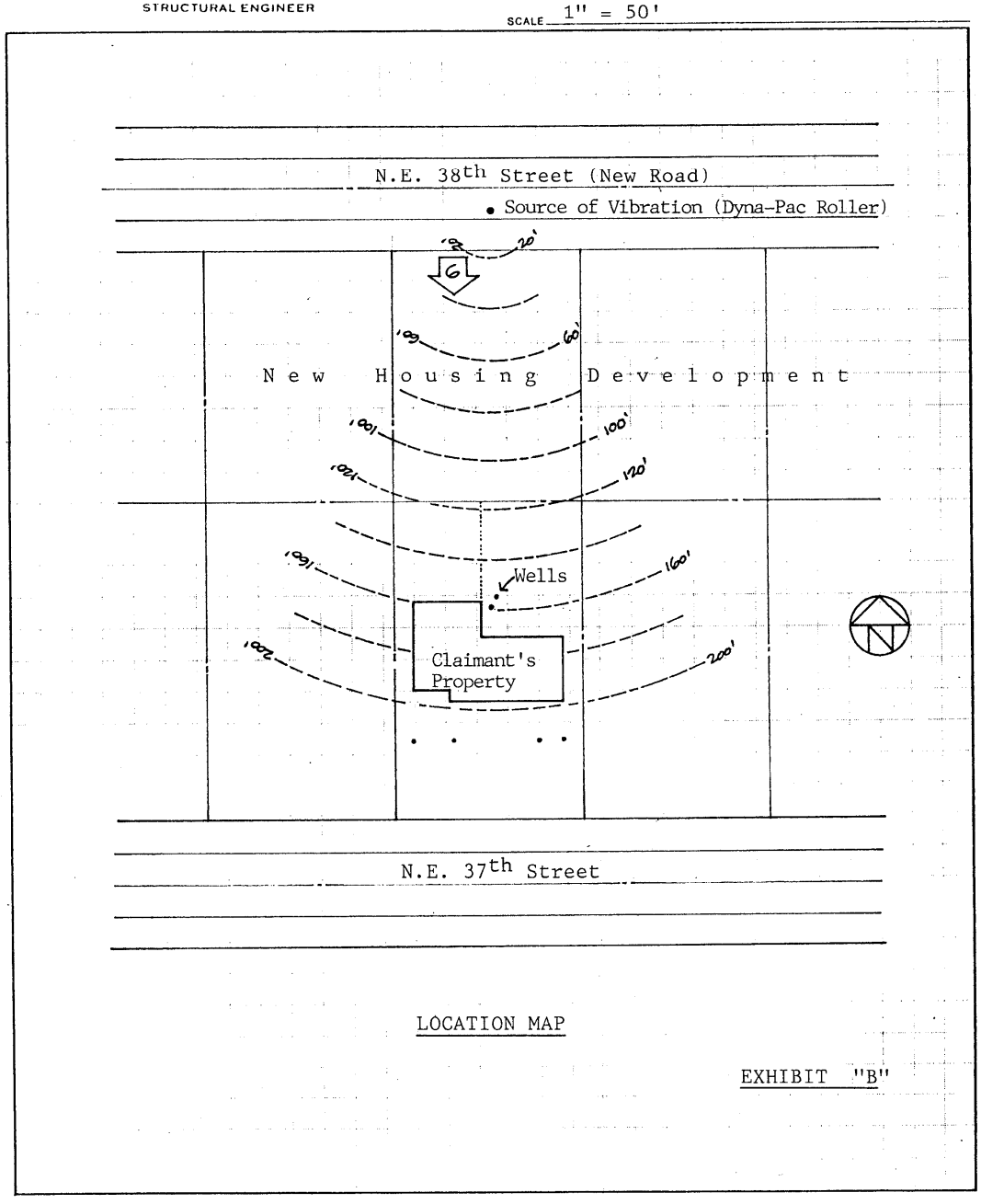


EXHIBIT "A"

PROJECT 204 1 /Ruben A. Gomez/ Inc., Groton, Mass. 01471

JOB 9367
SHEET NO. ____ OF ____
CALCULATED BY ____ DATE ____
CHECKED BY ____ DATE ____
SCALE 1" = 50'

RUBEN A. GOMEZ, P.E.
STRUCTURAL ENGINEER

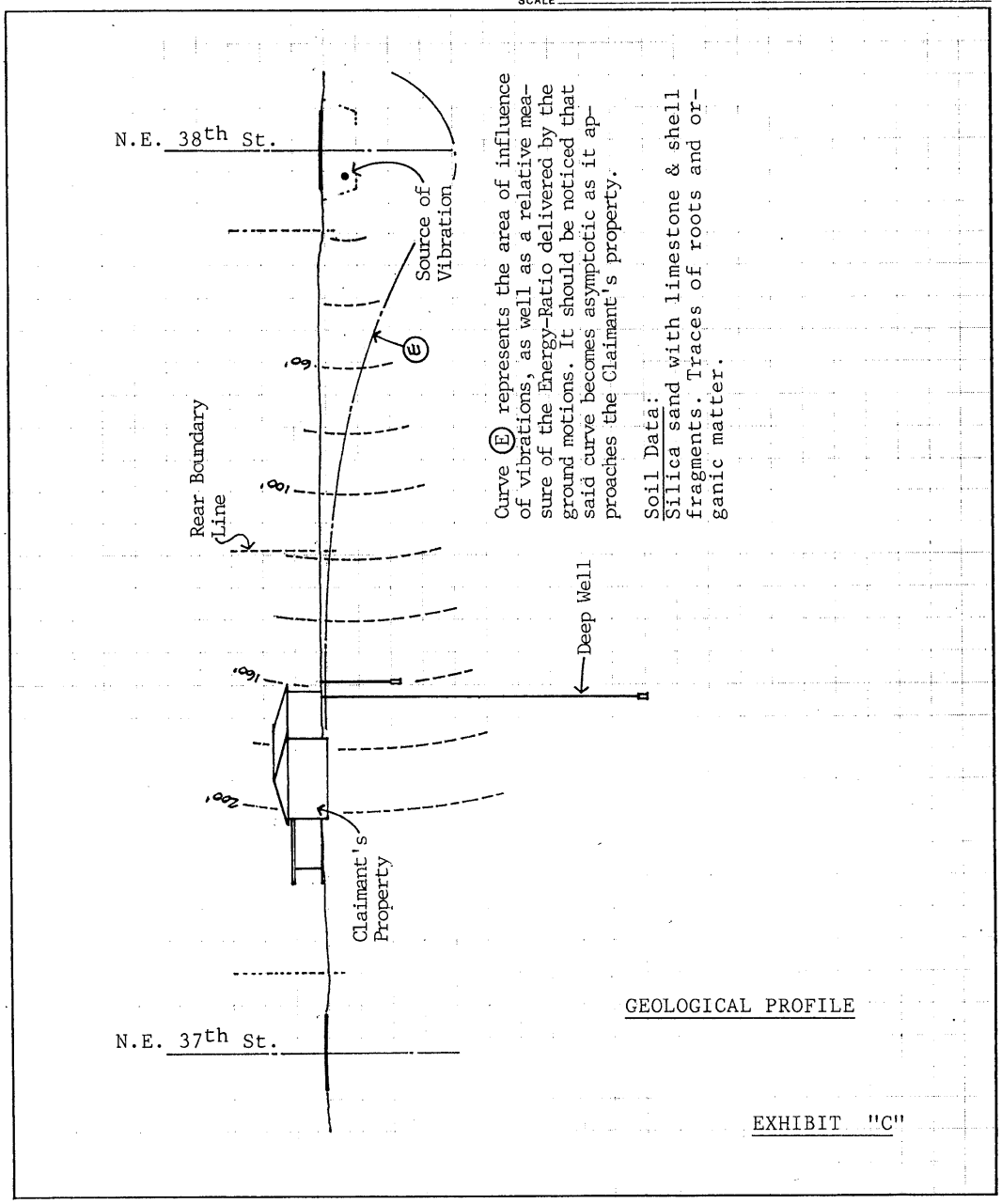


LOCATION MAP

EXHIBIT "B"

JOB 9367
SHEET NO. ____ OF ____
CALCULATED BY ____ DATE ____
CHECKED BY ____ DATE ____
SCALE 1" = 40'

RUBEN A. GOMEZ, P.E.
STRUCTURAL ENGINEER



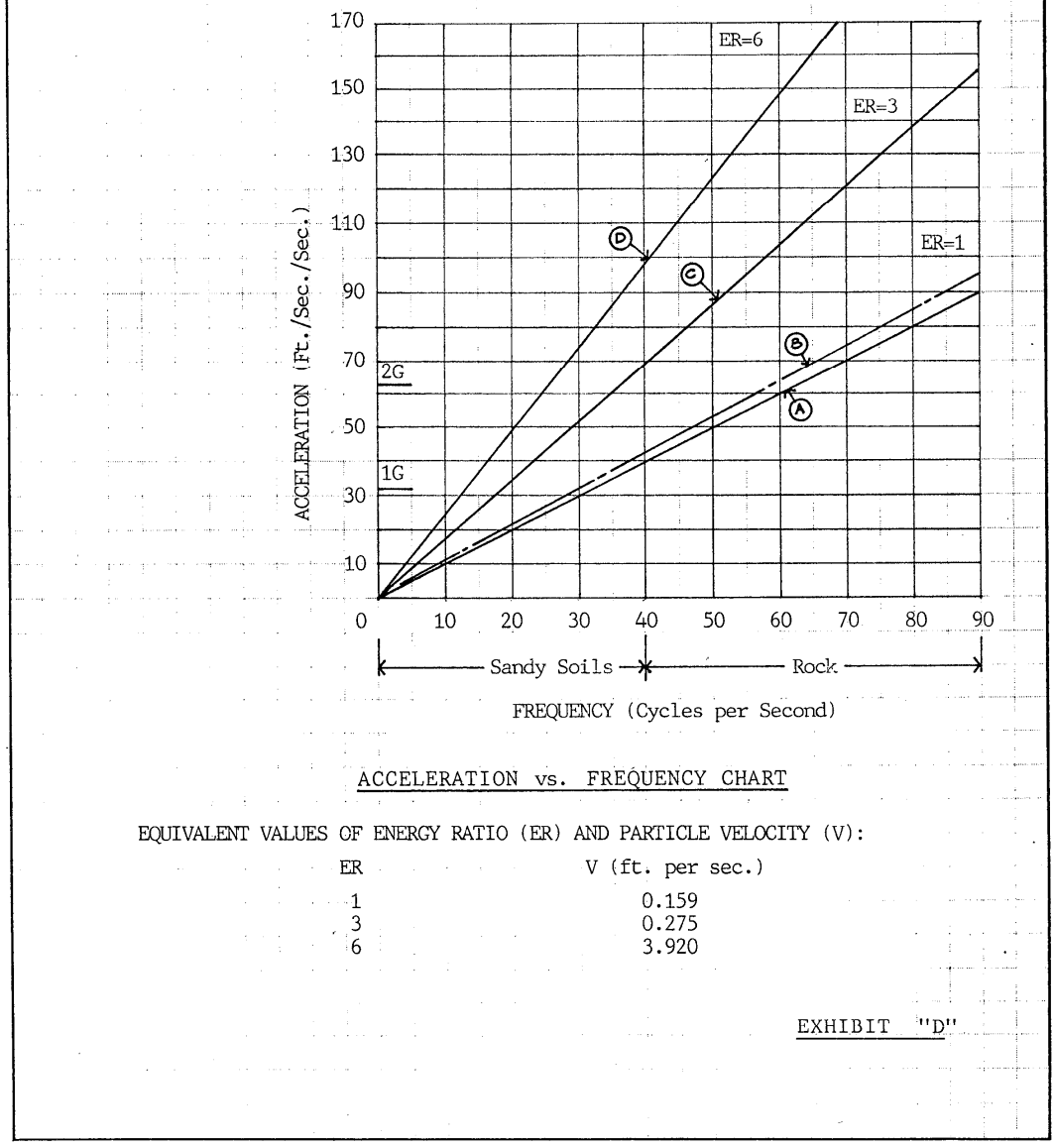
GEOLOGICAL PROFILE

EXHIBIT "C"

PRODUCT 204-1 /Acrimist/ Inc., Groton, Mass. 01471

JOB 9367
SHEET NO. OF
CALCULATED BY DATE
CHECKED BY DATE
SCALE

RUBEN A. GOMEZ, P.E.
STRUCTURAL ENGINEER



ACCELERATION vs. FREQUENCY CHART

EQUIVALENT VALUES OF ENERGY RATIO (ER) AND PARTICLE VELOCITY (V):

ER	V (ft. per sec.)
1	0.159
3	0.275
6	3.920

EXHIBIT "D"

PRODUCT 204 | Norwell Inc., Groton, Mass. 01471

JOB 9367
SHEET NO. ____ OF ____
CALCULATED BY ____ DATE ____
CHECKED BY ____ DATE ____
SCALE ____

RUBEN A. GOMEZ, P.E.
STRUCTURAL ENGINEER

FEATURES OF THE ACCELERATION vs. FREQUENCY CHART

(See Exhibit "D")

#1- Values of ENERGY-RATIO falling above line (D) represent vibrations which are damaging to conventional coonstruction.

#2- Values of ENERGY-RATIO falling between lines (C) and (D) represent vibrations that may cause damage to conventional construction and therefore, should be subject to careful monitoring.

#3- Values of ENERGY-RATIO falling between lines (A) and (C) represent vibrations generally safe for conventional construction.

#4- Line (B) represent the borderline as established by the U.S. Bureau of Mines, which is considered safe for standard buildings.

Field observations performed by Vibration Energy Services, Inc. on similar circumstances and where the same vibratory rollers (Dyna-Pac CA-25) were used, suggest the following findings:

POINT #	DISTANCE FROM SOURCE (ft.)	PARTICLE VELOCITY		ENERGY-RATIO
1	10	0.72 in/sec	(0.06 ft/sec)	0.142
2	25	0.30	(0.025)	0.025
3	35	0.24	(0.020)	0.016

If above ENERGY-RATIO values are plotted on the Acceleration vs. Frequency Chart on Exhibit "D", they will fall below line A , and are therefore, harmless to conventional construction.

EXHIBIT "E"

PRODUCT 204-1 [illegible] Inc., Groton, Mass. 01471.

6.0 PHOTOGRAPHS

6.1 The enclosed six (6) pictures have been included to provide visual documentation and support to the text herein.

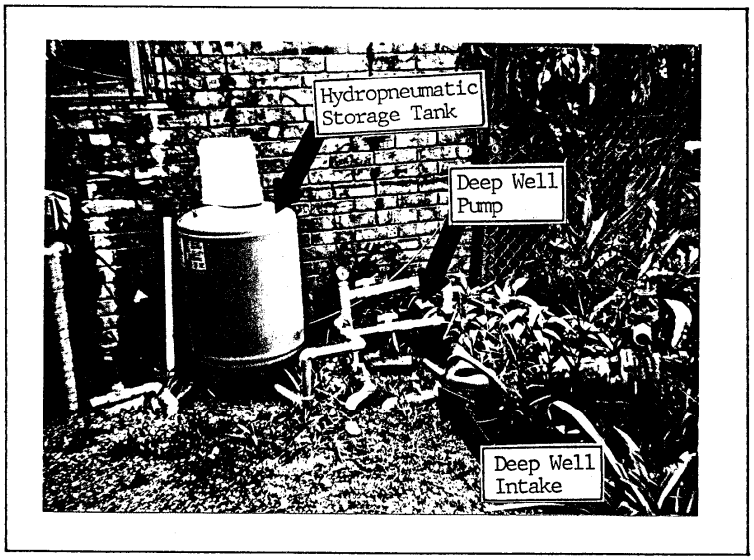
Author's Note:
Only Pictures #4 and #5 stood up to the ravages of time, the other four adhered to each other and were beyond salvage. They showed the property's front, back and side angles with no further consequences. Our sincere apologies.

PICTURE No. 4

Date Taken: 07-23-93 Camera Facing: Down

Subject Description: Water well equipment: Shallow well pump is on left. Light-blue tank adjacent to house's wall is the hydropneumatic storage tank.

Project: 9367



PICTURE No. 5

Date Taken: 07-23-93 Camera Facing: Northwest

Subject Description: View of pumping equipment.

Project: 9367

4.0 BEYOND THE REPORT

When one thinks of the reasons and motivations of the claim, as the centerpiece of this enclosed report, one cannot help but think of the human factors involved. On one hand, an old water supply system fed by an aging well on the very edge of its useful life and of course, the prospect of having to afford the cost to replace it. On the other hand, the inconvenience of being subject and having to endure all of the noise and the very uncomfortable vibrations which came along with a road construction project right behind your own backyard. If to all that, a third ingredient was added to the equation: *opportunity,* it may have seemed as the perfect scenario to get it all even and taken care of with one masterful stroke: *the claim.*

Thoughts of that nature are common contemplations in the mind of the examining forensic engineer. However, the principle of being objective must dominate his purpose above all else, for he should have as his ultimate goal the finding of the physical evidence and the truth, with no input from his preferences, emotions and prejudice.

5.0 POST-ANALYSIS & SELF-CRITIQUE

Enclosed Figure 5.1 has been assembled to show the two bullies of road and bridge construction. The upper picture shows two pile driving crawler rigs both equipped with a 14,000 pound diesel pile hammer, while the lower picture depicts a 24 ton vibratory roller. We have referred to them as "bullies" because that is what they really are, for they frighten the neighborhood residents but only in a few extreme cases have they lived up to the menacing image they project.

There is another item that is worth mentioning because it seems to defy logic, which is the following:

a. please read the statement in Paragraph 3.3 of the report saying: "A [The] deep water well is being used for drinking water supply, and a shallow well is used for irrigation purposes. According to the Claimant's statements, the deep water well has collapsed and the shallow well is still working satisfactorily."

b. now please study the profile on Exhibit C. Compare the E curve against the locations of the shallow and deep wells. Wouldn't logic dictates that when it comes to the vibratory pattern, the shallow well should have been affected first rather than the opposite? Should have we succumbed to "the paradox of the field observations" or rather allowed logic to prevail? We chose the latter.

We will take the time to go over the following considerations because the subject of ground vibrations can be very baffling, confusing and discouraging to the forensic

engineer. Yet, there are certain common grounds which, if taken into account, would bring light to a problem seemingly very obscure at times.

As part of the mental challenge we will be shuffling the factors described on three different scenarios:

a. A summary of a report from Vibration Energy Services Incorporated (VESI) on their observations in January 1993.

b. The contents of the above enclosed report as the field conditions were observed in July 1993.

c. The author's observations as they took place on the above described road widening project in North Miami in early 1994.

On the first scenario, we have transcribed information contained in VESI's report dated January 25, 1993. The project was an asphalt road paving on S.W. 3rd Street in Boca Raton, Florida. The paving contractor used a DynaPac-25 vibratory roller and readings

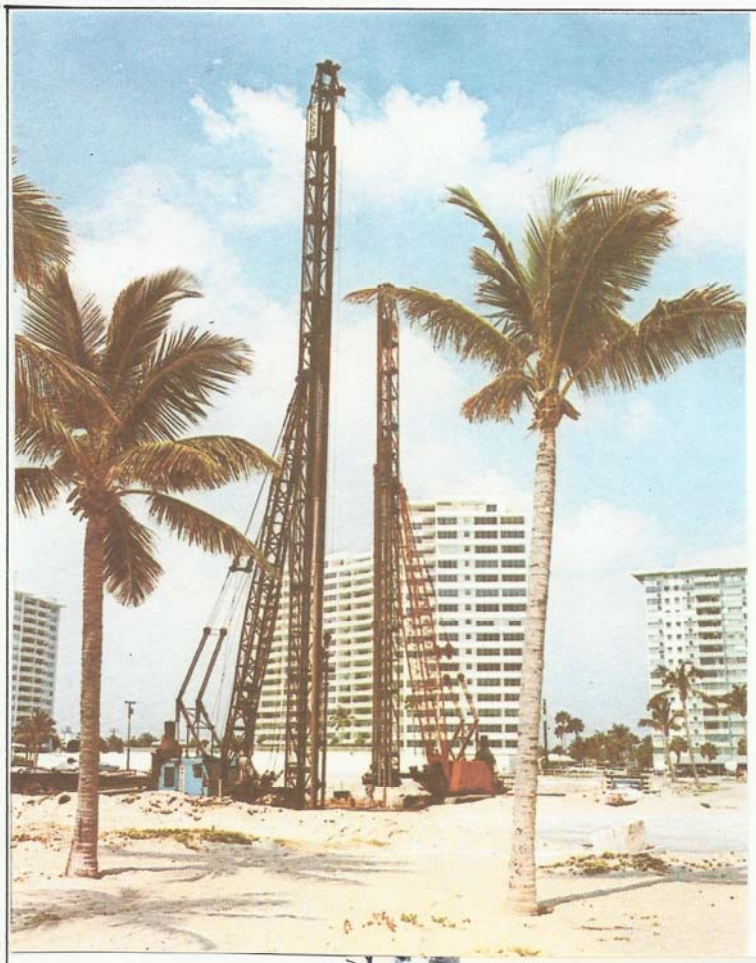


FIGURE 5.1

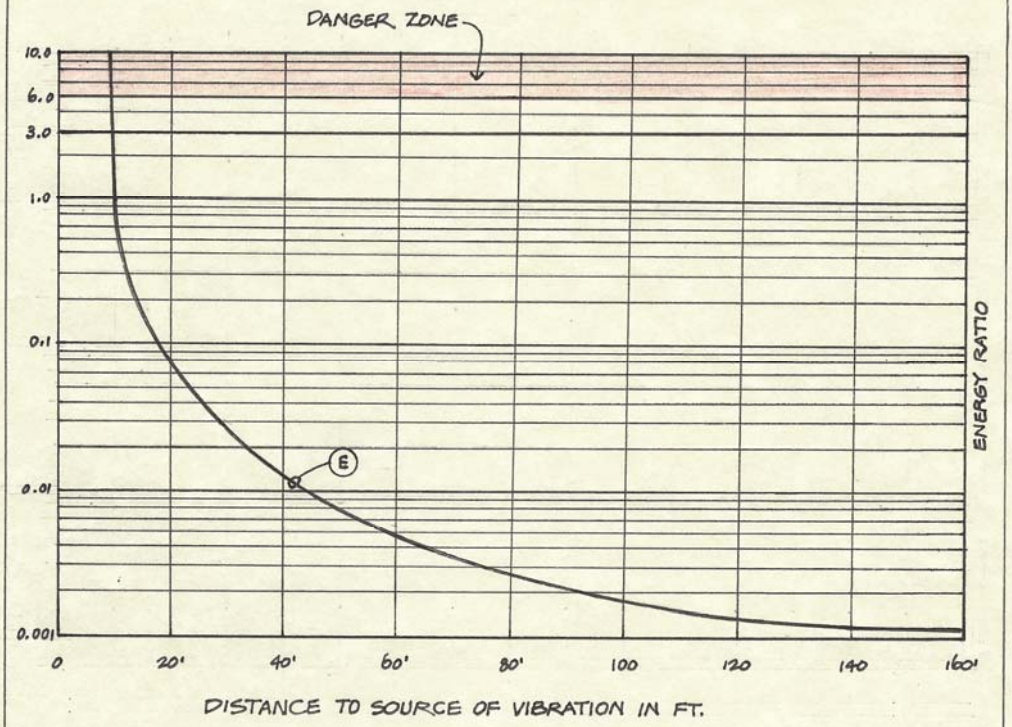


FIGURE 5.2

This graph is an extrapolation of the "Liberty Mutual's Graph" which was necessary to cover the 160 ft. from the vibration source to the deep well.

Applicability of this graph is limited to SANDY soils only.

All of the Energy-Ratio values shown on this course have been calculated by using the "Crandell's Formula": ER = 39.47 times "v" squared, where 39.47 is a constant and "v" is the "particle velocity".

were taken with a VESI's personnel by using a NSCS 5000 digital seismograph at distances measured from the fully operating roller, ranging from 10 to 50 ft.

Peak Particle Velocity (PPV) readings were an average of 0.72 in/sec at distances of 10 ft. PPV at a distance of 25 ft. was 0.30 in/sec and 0.24 in/sec at 50 ft.

When you consider that the U.S Bureau of Mines after 75 years of continuous field experience and research has concluded that ground vibrations of less than 2.0 in/sec are safe to handle for the common structures found in the United States. Consequently, those values as measured by VESI are indeed insignificant in comparison.

On the second scenario, although the forensic engineer was obviously too late to have obtained actual instrument readings, however, based on the facts gathered during his site examination there was little doubt left of the impossibility of any damage to the deep well. In that respect, please study the graph which is part of the enclosed Figure 5.2. Such graph is an extrapolation of the original known as the "Liberty Mutual's Graph". Please also study the prevailing conditions as described on Case #9367. If you observe the "E" curve on Figure 5.2 you will notice that at a distance of 160 ft. the Energy-Ratio should be about 0.0012, which for practical purposes is a value closed to negligible. That was substantially the discerning base supporting the recommendation for the rejection of the claim as indicated on Paragraph 4.1 of said report.

On the third scenario, the reader can appreciate how the direct observations of this author concur with the findings of independent members of the industry by which the generalized opinion is that the vibrations generated by the two "bullies" of the road construction experience are for the most part over exaggerated, mainly because in a great extent the human response to vibrations is too acute to be used as a guide to the expected damage.

Before closing this part of the series it must be said that most of the statements and affirmations made on this course are referring to vibratory waves propagating through *sandy* soils. It must also be emphasized that wave propagation is affected by the media it moves through, therefore, it is a different matter when such propagation takes place through clay, gravel or rocky soils or water for that matter, for their propagation flow has to be evaluated on their own merits and mostly tend to higher values.

Another qualification that is pertinent to be considered here is *fatigue* as a function of *frequency* and *event duration.* Construction materials are all susceptible to fatigue and just because a given material behaves well under the effect of an event lasting 50 cycles it does not mean it will continue to do so after another 500 cycles. Therefore, the *duration* of the vibratory event plays an important role in the material's performance. Please keep that in mind.

END