03 Jun 1993, 10:30 am - 12:30 pm

Distress — Cause and Effect: A Diagnostic Study

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Proceedings: Third International Conference on Case Histories in Geotechnical Engineering, St. Louis, Missouri, June 1-4, 1993, Paper No. 8.21

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SYNOPSIS: Detailed site investigation, rigorous analysis and smart design of any engineering project prove to offer a successful product provided Quality Control and Quality Assurance are enforced during the construction phase. Failure to comply with QA/QC led to premature distress and extensive damage. A typical case, where negligence to address extenuating problems that arose during the construction stage resulted in severe damage is investigated and reported. Post-construction diagnostic study to unravel the cause and effect is presented.

BACKGROUND

A shopping mall about 170,000 square foot of floor area and about 1,000 parking stalls was developed in Eastern Pennsylvania. A site plan, Figure 1 shows the layout of the shopping mall and the parking lot. Initial geotechnical investigations indicated the presence of silty sand (SP) and silt with shale fragments and clay (ML) up to a depth of 12 feet underlain by bedrock. A cross-section of the site is shown in Figure 2. The SPT - N Values ranged from 4 to 160 blows/foot indicating the soil varied from loose to very dense. Water table was not encountered within the depths of the borings. The coefficient of permeability of the sandy soil was estimated to be 10^{-3} cm/sec.

The California Bearing Ratio for the soil at this site was determined to be 13. For typical traffic conditions of a shopping mall, an asphalt concrete surface course of three inches with a graded aggregate base of nine inches was recommended for the passenger car parking area. Three inches of asphalt surface course with a twelve inch thick graded aggregate base for entrances and traffic lanes were suggested.

The buildings along with the pavement were constructed during fall of 1989 and spring of 1990. During the winter of 1989, the pavement heaved at several locations. During the spring of 1990, the pavement cracked at several locations and was pumping. Two geotechnical testing and consulting firms were hired by the owner to investigate the reasons for the failure of the pavement.

TESTING PROGRAM

One testing laboratory took 31 core samples of the pavement to determine the thickness of the surface course, the binder course, and the base. The location of the water table and the water content of the base material were also determined. The other testing laboratory took ten core samples of the pavement at or near locations selected by the other laboratory for comparison of the results.

RESULTS OF THE TESTING PROGRAM

Only three core samples (7%) did not meet the thickness requirements of the asphalt surface out of a total of 41 core samples taken by both laboratories. Standing water was observed at ten locations (24%) and saturated base was reported at 18 locations (44%). The base course material did not meet the thickness specification requirements at 14 locations (34%). At least at 10 locations (25%), large boulders were found within the base.

ANALYSIS OF TEST RESULTS

The results showed that there was not any significant deviation from the pavement specifications. However the presence of standing water and saturated base raised a serious question about the source of the water table found which was not present while the site was investigated initially. Testing of standing water at the site by a third testing laboratory indicated the presence of chlorine in the water. So, one probable source of the excess water that inundated the lot could be from a leaky drinking water main. An examination of the daily logs of the progress of work kept by the general contractor revealed the stagnation of water, long after the rainfall season.

Photos taken during construction showed water stagnation at several locations in the parking lot. The arrangement of catch basins, and drainage during construction are shown in Figure 3. Water stagnation was cited due to clogging of gravel around temporary raisers in the catch basin. Four inches of water from Basin 1 was pumped out in July 1990 to complete the final stabilization of the basin itself. The presence of the increased moisture content could have resulted in adverse effects on site compaction and its strength.

The monthly progress reports kept by the general contractor show a water main rupture in september 1990, discharging more than 40,000 gallons of water at the site. Subsequently, there were two other incidents of ruptured PVC water lines on

November 7th and 13th which resulted an additional discharge of 16,000 gallons into the site. Unfortunately, there is no record to determine the quantity of water entered or discharged into the site. The rock formation at the site and the lack of efficient drainage system acted like a "soup bowel" retaining most of the water that entered into the site. Increase of hydrostatic pressure resulted in the heaving of the pavement and finally pumping at several locations. A few construction flaws compounded with excessive uplift pressure caused severe damage to the pavement.

The effects of the high water table during construction and the presence of large stones in the base course on compaction and stabilization of the site are not known presently. The lack of surface drainage systems which were mandated in the specifications during construction seems to have imparted heavy damage to the quality of construction. Furthermore, additional flooding from external sources and the poor subdrainage conditions greatly aggravated the problem.

CONSULTANT'S RECOMMENDATIONS

The immediate need to install a subdrainage system was greatly stressed. A "Poroswall" concrete pipe system for subdrainage was suggested. Continued observation of the performance of the system for at least some time was strongly recommended. Radial bleeders which were in the original plan were proposed to either repair or reinstall as the situation demands. The recommendations also included undercutting of the asphalt surface course at the problem areas of the pavement and resurfacing.

REPAIR AND REHABILITATION

The recommended remedial measures were carried out during the summer of 1992. A recent site investigation revealed no water stagnation and no new surface cracks.

CONCLUSIONS

The poor surface, subdrainage, the water spill by the water main breakage, and the service pipe leakage contributed to the water logging problem at the project site. It resulted in the pavement deterioration and failure. A better inspection program adhering to the project specifications and prompt response to unforeseen problem sources during construction could have helped to avoid the premature pavement distress. The lessons learned due to such failures would facilitate better construction management in the future.

REFERENCES

Unpublished reports from the senior author's personal files.

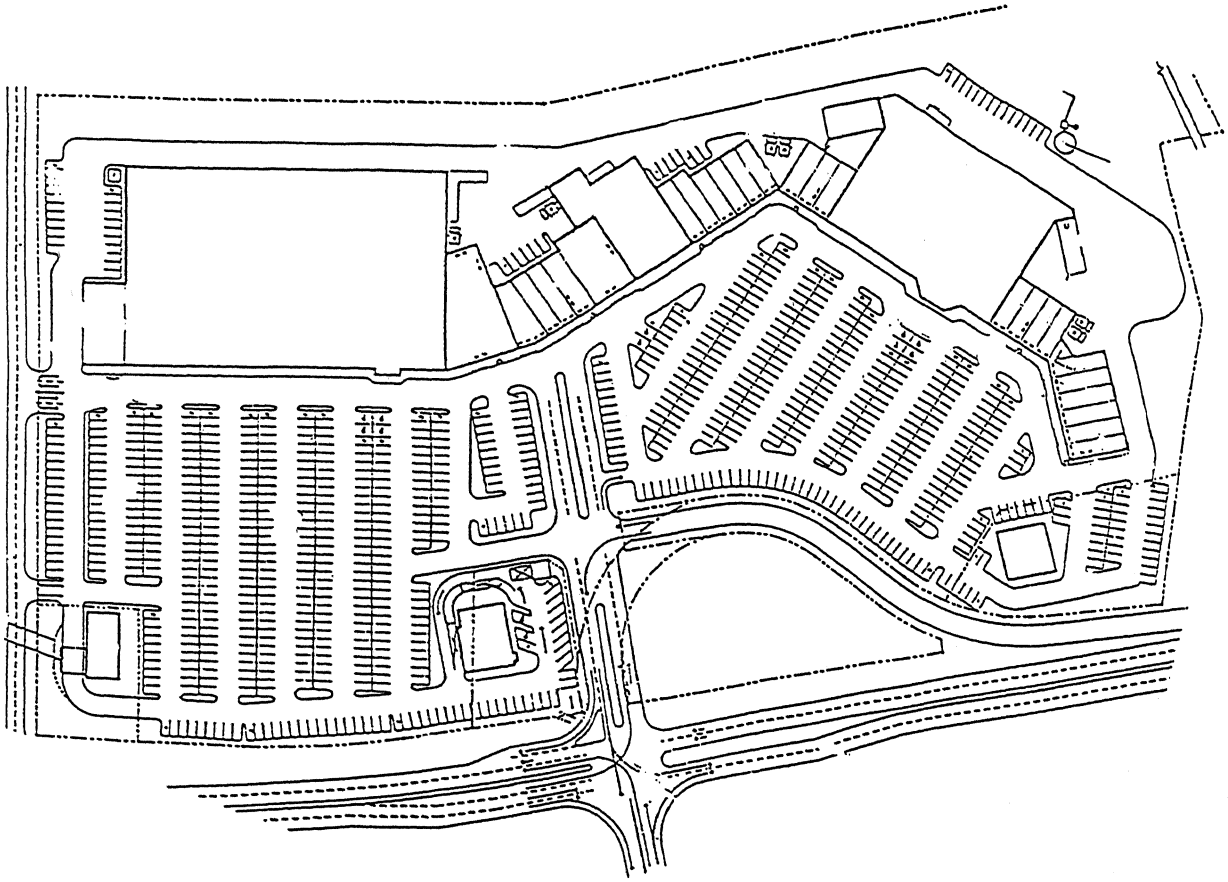

Figure 1 - Layout of the shopping mall and the parking lot.

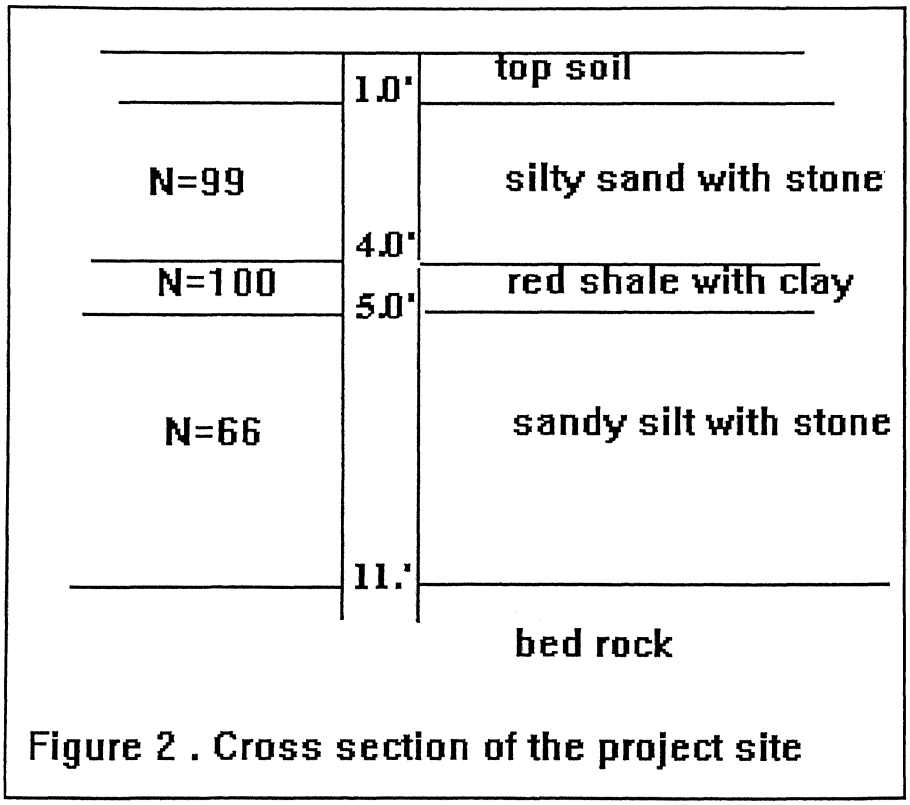

Figure 2 . Cross section of the project site

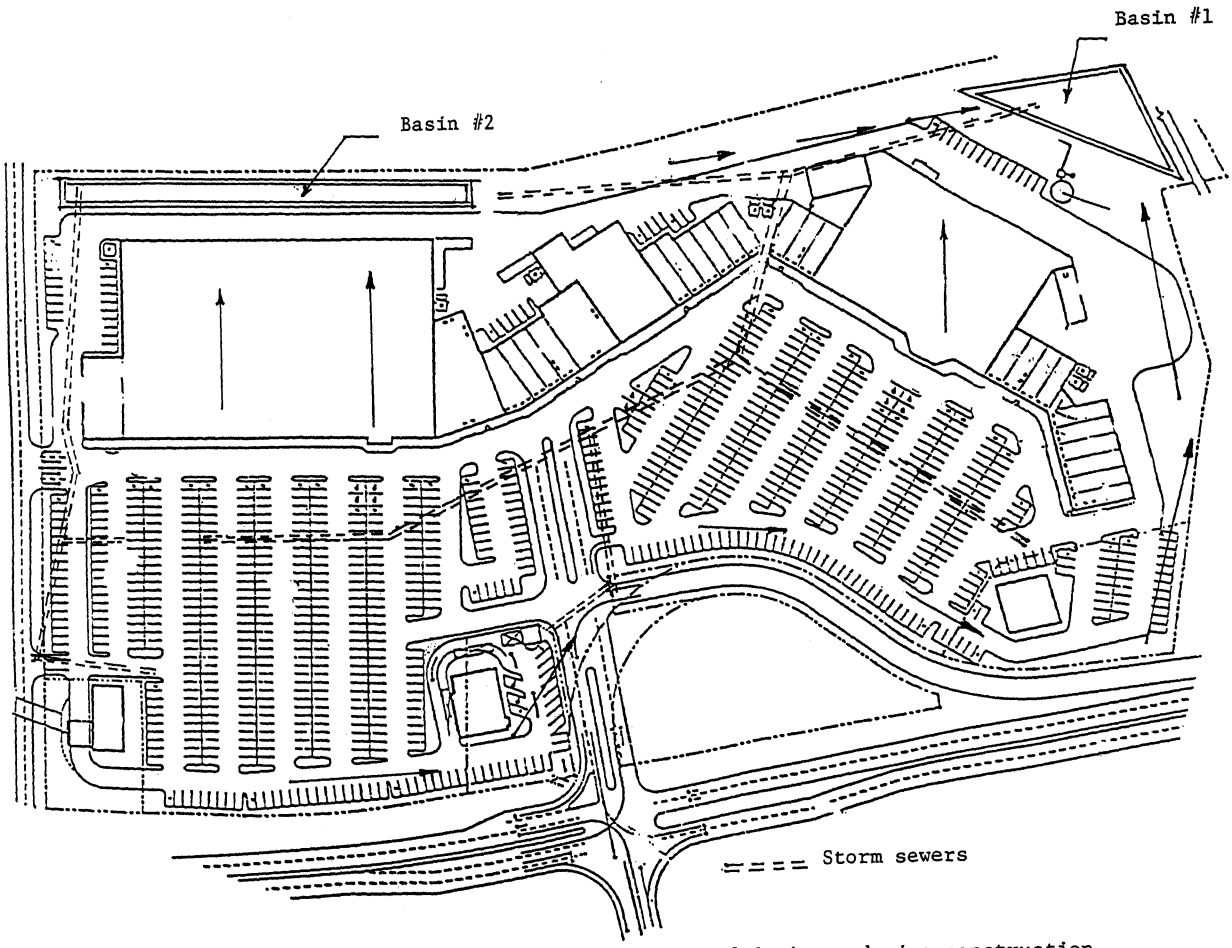

Figure 3 - Arrangement of catch basins and direction of drainage during construction.