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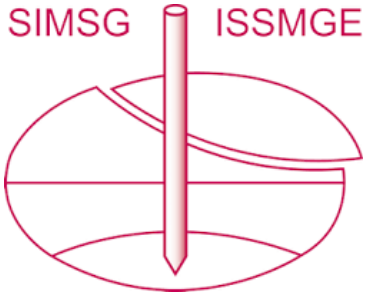

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Unconventional seepage control approach for a substructure

Etude des mesures innovantes de controle de l'infiltration d'eau Dans des fondations

S. Kibria
General Manager, GT & GE Division, NESPAK, Lahore, Pakistan
G. Hassan
Advisor, GT & GE Division, NESPAK, Lahore, Pakistan
T. Masood
Chief Executive, Berkeley Associates, Lahore, Pakistan
M. Saleem
Senior Geologist, GT & GE Division NESPAK, Lahore, Pakistan

ABSTRACT

The requirement of an effective control of water in underground R.C. structures located below ground water table, poses a big challenge to civil designers and constructors. The advent of a broad range of admixtures and products has heralded new vistas for effective control of seepage in the submerged structures. However, the whole range of measures that can be adopted for the control of seepage in the substructures yet to be constructed is quite different from that to be implemented for the existing substructures.

Recently an underground R.C. structure constructed in the saturated ground, in Punjab in Pakistan, developed serious seepage problem. The seepage was so intense that it could be seen from 3 feet thick well-compacted dense concrete exterior walls of the substructure, sitting in fine sand deposits. The initial scrutiny revealed that the design stage damp proofing measures (including use of water-proofing admixture, application of cementitious coating and geomembrane wrap- around) were not implemented carefully during construction.

After a detailed study into the problem, hydrated lime slurry was systematically injected in the ground through a series of closely spaced 4 inches diameter primary boreholes, drilled in the vicinity of the outer face of the substructure. A series of secondary and tertiary bores and injections were also carried out, on the basis of closely monitored seepage response. The seepage was found to stop effectively in about six to eight weeks time following lime injection, when the micro pores in the R.C. walls were properly sealed. Subsequently, the negative side of exterior walls was dried with blowers/ heaters and epoxy was injected in a controlled manner. This whole process of seepage control for the substructure has been implemented with remarkable success, without lowering the groundwater table.

This paper presents an account of the unconventional seepage control measures successfully implemented for a submerged structure.

EXTRAIT

Le besoin d'un contrôle effectif de l'infiltration de l'eau dans les sous-structures en béton armé situées en dessous des nappes phréatiques pose un grand problème aux ingénieurs ainsi qu'aux constructeurs. L'avènement d'un large éventail d'adjuvants et de produits a ouvert de nouvelles portes pour le contrôle efficace de l'infiltration dans les structures immergées. Cependant, la gamme complète des mesures qui peuvent être adoptées pour le contrôle de l'infiltration sera très différente selon que les sous-structures existent déjà ou doivent être construites.

Récemment, une sous-structure en béton armé construite dans des sols saturés dans le Punjab au Pakistan, a connu de sérieux problèmes d'infiltration d'eau. L'infiltration était si intense que l'on pouvait la voir à l'extérieur des murs en béton armé dense d'une épaisseur de 3 pieds (*feet*) de la sous-structure, qui été construite sur une couche de sable fin. Le premier examen du problème a révélé que les mesures d'imperméabilisation à l'humidité recommandées par les concepteurs (notamment l'utilisation d'adjuvants étanches, l'enduit d'une couche de ciment, et le revêtement d'une géomembrane) n'avaient pas été scrupuleusement respectées et mises en œuvre durant la construction.

Après une étude détaillée du problème, de la chaux hydratée a été systématiquement injectée dans le sol grâce à une série de forages primaires très rapprochés d'environ 100 mm de diamètre (soit exactement *4 inches*), forés à proximité de la face extérieure de la fondation. Une série de forage et d'injections secondaires et tertiaires a également été effectuée, en réponse à toute infiltration observée. Il a été constaté que l'infiltration a cessé après environ six à huit semaines suite à l'injection de la chaux, lorsque les micros pores dans les murs en bétons armés ont été correctement scellés. Ensuite, le coté intérieur des murs extérieur a été séché par soufflantes / chauffages et de la résine époxy a été injectée de manière contrôlée. Ce processus de contrôle d'infiltration de la fondation a été un remarquable succès et ce, sans que la nappe phréatique soit abaissée.

Cet article présente un compte rendu des mesures innovantes de contrôle de l'infiltration mise en œuvre avec succès dans le cadre d'une structure immergée en dessous de la nappe phréatique.

Keywords: Seepage, Substructure, Geomembrane, Submerged, Admixtures, Hydrated lime

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1 INTRODUCTION

During construction of an underground structure in Punjab in Pakistan, seepage of groundwater started through the 3 ft thick and compacted concrete walls, when dewatering was terminated. The ground consists of medium-dense fine sands, with groundwater table present close to the ground surface.

Dampness and seepage was observed through the outer walls of the structure and through the construction joints. Ingress of water and salts through the concrete walls and construction joints was observed. The pH value of water was reported as 7 during construction and before lime injection.

2 DETAIL OF SEEPAGE CONTROL MEASURES

Seepage control measures provided during the construction as per original design included the use of water-proofing admixtures, coating of cementitious material and the wrapping of geo membrane at walls. During the construction, these measures for the control of seepage were not carefully implemented. The geo membrane was punctured at different spots while placing the protection material (gravels <3″). The water table was kept 3 ft below the foundation level during the construction by dewatering the area (26 feet of dewatering). A detailed dewatering system including dewatering pumps was provided to control the seepage during construction and operation.

3 CHRONOLOGY OF SEEPAGE AND ITS MAGNITUDE

During the construction stage, dewatering of the area was terminated when the construction activities reached at a level above the ground water table. Due to rise of water table to its initial level, seepage of water started through the concrete walls, construction joints and along the embedded steel items. The ingress of water with salts (chlorides and sulphates) through concrete would be a reason for the gradual steel corrosion. The water that percolated through the walls was also trapped within the walls and the plaster. The dampness was observed on the all outer walls besides the seepage. The seepage water was accumulated at floor of the structure overnight, which was dewatered manually. The depth of water on the floor sometimes exceeded 2 ft. Seepage had also started from the floor and the roofs slabs at a few locations. The quantity of water accumulated overnight was measured as several hundred liters. This was considered to be an alarming situation which required special attention. A detailed study was therefore carried out to investigate the problem and to implement the measures to control the seepage.

4 OPTIONS FOR SEEPAGE MITIGATION

A host of options were studied to control the seepage taking place through the structure, as follows:

i. Installation of permanent dewatering system.
ii. Provision of cut-off wall (silty/clayey material) around the structure.
iii. Re-installation of geo-membrane after deep excavation and dewatering
iv. External treatment (Lime Injection).
v. Internal treatment (injection of epoxy based solutions)

Keeping in view the intensity of seepage, workability of method to be adopted and effectiveness to minimize the steel corrosion, the following remedial measures were suggested to control/minimize the seepage and steel corrosion.

- External Treatment
  Injection of hydrated lime all around the structure in 4 inches dia and 7 ft to 35 ft deep boreholes;
  - To increase the pH value of the groundwater
  - To fill the minute pores in the concrete walls
  - To block other seepage points in concrete walls.
- Internal Treatment
  - Injection of epoxy based solutions into the seepage holes
  - Sealing of these holes with epoxy
  - Application of plaster, containing water proofing agent.

The option of external treatment was adopted initially to minimize the seepage. This technique remained very effective and made the interior of the structure workable. The second option of internal treatment was adopted as a supporting measure to lime injection process and to make the structure totally water tight and free of seepage.

5 IMPLIMENATATION OF LIME INJECTION PROGRAMME

It was planned to inject the hydrated lime slurry along the exterior walls of the structure. The following procedure was adopted to complete this process successfully:

- Delineation of the most affected areas and to inject the lime in these areas on priority.
- Drilling of 4″ dia vertical boreholes at 5 ft to 10 ft interval and ranging in depth from 7 ft to 35 ft.
- Injection of hydrated lime through the boreholes, in ascending order. The lime was injected through gravity as well as pressure injection by using the mechanical packers @ of one metric ton of powdered lime/hole up to refusal.
- Backfilling of holes with cement-bentonite-soil mix.

The hydrated lime slurry was prepared in grout mixers in 3:1 ratio. Sodium Silicate (2-3%) was used as admixture for quick setting of lime in the minute pores and other seepage paths. The hydrated lime was also injected through all around shock damping layer of gravels/cobbles directly, without drilling any hole. This technique was found to be very effective to control the seepage through the roof slab.

The injection of lime also helped to locate and identify the seepage paths, due to continuous flow of lime through these holes and construction joints. Some holes were also drilled up to the gravel/cobble layer above the roof slab to reduce the lime travel path and to make it effective. At a few locations, the drilling was not possible due to accessibility problems. At these locations, lime was directly poured in the gravel/cobble layer without drilling of boreholes. Every possible step was adopted to ensure circulation of lime slurry through all the available seepage paths on the basis of close monitoring of lime injection process and its effectiveness. The seepage was generally effectively reduced by external lime treatment. The seepage at a few points, however, could not be controlled by lime injection, although it was significantly reduced.

Internal treatment was carried out on the negative side of the walls to control the seepage at these locations. The plaster was removed from these locations and the concrete surface was cleaned and dried. Small holes of 5mm dia and length of 150 mm were drilled at the seepage points and epoxy based material was pressure injected in these holes. The holes were sealed with bonding agents and plaster, containing water proofing material. If the remaining minor seepage was not controlled with the first attempt of epoxy injection, the process was repeated until the seepage was completely eliminated.

6 MONITORING OF SEEPAGE, FOLLOWING TREATMENT

- The seepage points were identified and marked for daily monitoring.
- The overnight flow of water was measured every morning, which was found to reduce gradually as the lime injection proceeded.
- Monitoring of pH value of the seeped water which was enhanced from 7 to 12.

Fig-1 shows a systematic reduction in seepage quantity with time.

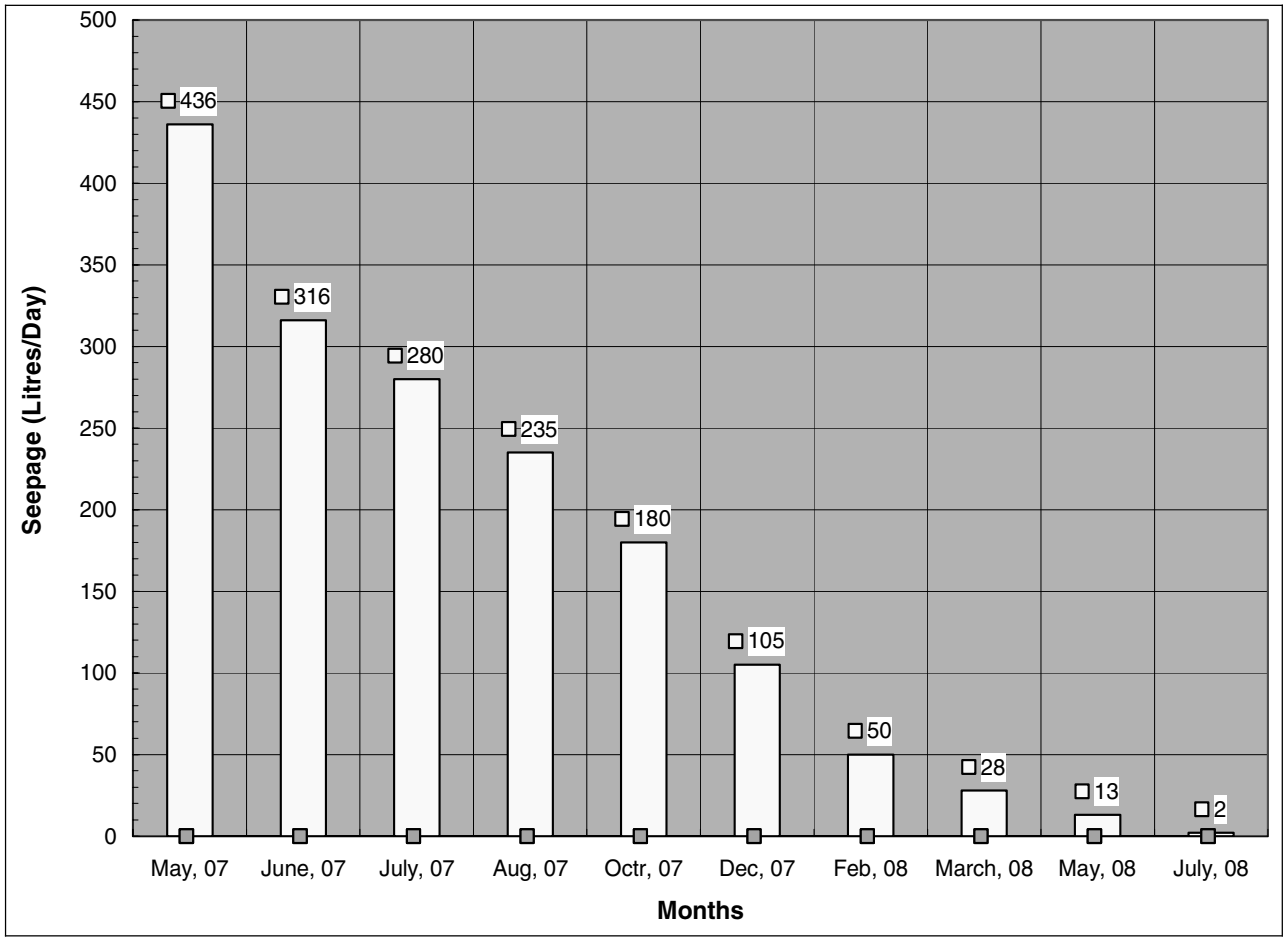

Fig. – 1 Seepage Monitoring at an underground structure at Punjab Pakistan

7 CONCLUSIONS AND RECOMMENDATIONS

- The installation of geo-membrane as a water sealant, for underground structures in saturated conditions, needs special attention.
- The stone to be used in the vicinity of membrane around the structure, should not be angular or with sharp edges.
- Placing and dressing of stone layer should be manual, instead of using any equipment.
- Plaster should be applied to the walls after the checking of the walls for seepage by terminating the dewatering system temporarily.
- Instead of using geo-membrane, the adhesive membrane or other water proofing membrane (like rubberized coating) may be used.
- Lime injection should be carried out as close as possible to the affected areas.
- The process of lime injection may be repeated at those locations where the seepage remains uncontrolled or the pH value at a negative (inner) side has not attained the desired level.
- The perforated stand pipes may be placed, as a precautionary measure in the shock proof stone layer all around the structure, to avoid the drilling of boreholes in the backfill zone. Thee stand pipes can be used for lime injection if there is any seepage in future.

- The quantity of lime required for seepage control depends on the site conditions.
- The internal treatment at negative (inner) side of the walls should be carried out, even if the seepage is controlled with lime injection, to avoid any complication in future.

REFERENCES

Annual Book of ASTM Standards (2003)

Bishop, D., Kohlhase, S.,Johannben, K.. (1994): Recent application of modern geosynthetics for coastal, canal and river works. Fifth International conference on Geotextiles, Geomembranes and related products, Singapore, September, pp. 545-548.

DVWK (1994): DVWK Guidelines for water management 307 (1994): Application of geomembrane in hydraulic engineering and groundwater protection. (Ed. German Association For Water Resources and Land Improvement).