Need and Awareness of Leakages and waterproofing in High rise Building

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Abstract. Identification of leakage sources is itself a perplexing process and needs expert views from experienced work and trade specific professionals. Comprehensive strategies relevant to work methodologies are to be implemented that prioritises durability and efficacy of waterproofing system. Leakages when identified at final stages of building handovers induces a high cost in repair and maintenance of defects pertaining to waterproofing failures or due to non-consideration of leakage prevention measures at the design and specification establishment stages. Despite of a thorough technical knowledge even seasoned civil engineering professionals and even waterproofing specialists are not aware of the probable root causes of observed leakages. Various factors contributing to leakages through different areas of buildings are mentioned along with preventive measures in relation to process enhancement, workmanship, materials, etc. in relation to prevention of leakages. Photographic examples of different types of leakages are provided for an easy understanding of non-technical users regarding the kind of defect being discussed. This study represents a comprehensive review of different types of leakages observed in buildings and their root causes. Solutions based on type of leakage along with the specific materials and method orientation for the relevant leakages is also covered in the study. Waterproofing is an essential aspect and integral part of building construction which ensures the durability, longevity, and structural integrity of buildings. Proper waterproofing safeguards the structure from observable and non-observable damages such as internal or external structural disintegration, Waterproofing although being a complicated activity, is highly generalized in terms of materials to be used. This research explores the different types of materials and their required specifications to be used or not to be used at a particular location in buildings along with listed reasons.

Key Words: Building Leakages, Customized solutions, Durability, Waterproofing, leakage preventive measures

1. Introduction

Construction industry from the past years has advanced to a vast extent with latest technologies arising day by day for facilitation of the respective works and activities. Although workmanship based leakages can be avoided through stringent work inspections, system and process based leakages bear no relation with good or bad workmanship. In order to prevent such leakages, we should be able to predict the possibility of leakage in future, incorporate and implement counter leakage prevention system against the susceptible areas. Leakages as the name suggests, are mostly observed when whole construction work or even customer handovers are over. Majority of such leakages would have been avoided by acting on the root causes at construction stage only, which are

primarily related to systems, materials and workmanship inspections. An awareness and knowledge concerning the root causes of leakages will help prevent them from occurring including saving of unnecessary costs related to the repair and rectification processes. Thus, the knowledge of types of leakages and their specific root-cause based preventive measures is the need of the hour. The criticality of building leakages has taught that waterproofing is not merely an option but a fundamental necessity in Building Construction. Unfortunately, despite of so many advancements in technology in Civil Engineering, the subject specialization and awareness of waterproofing process, products and materials is majorly limited to waterproofing industry professionals only. Due to this lack of awareness in waterproofing processes, many times the customers and civil engineers observes leakages even after use of waterproofing products. This is majorly due to poor selection of materials, wrong usage, lack of consultation from product manufacturers or no review of product technical data sheets. Each product is developed and manufactured with specific uses and designated places of use. One product suitable for a particular condition may prove to be a failure if used at other location and vice-versa. In addition, any product if not used correctly as per specifications and instructions may result in system failures. Thus, a thorough study and knowledge of waterproofing products is required before using them in construction process or for maintenance purposes.

1.1 Importance of waterproofing as an integral part of construction

Water intrusion poses a high risk to buildings, whether residential, commercial, high-rise or individual houses. Water when penetrated inside structural members such as beams, slabs, walls, etc. due to any reason such as leakages, it can even lead to structural deterioration with passing time and may even reach to critical levels. Apart from the structural concerns, the relentless effects of leaked water constantly challenge the comfort and satisfaction of occupants. This underscores the paramount importance of waterproofing and leakages prevention measures, which although being a critical facet of construction processes is often underestimated and neglected until the disaster strikes. However, the maintenance costs pertaining to treatment of leakages can be a lot higher than imagined, even more than the cost of waterproofing measures that could have been taken at construction stages and prevented the leakages from occurring on first hand. From the past decades of experiences in residential mega projects, leakages have emerged to be one of the most critical concerns pertaining to customer dissatisfaction, conflicts and high maintenance costs, and have proved to be a nightmare for Project Management and Civil Engineering professionals.

1.2 Necessity for waterproofing to enhanced durability of structure

Concrete is a prominent material that is unparalleled in the use for building and other construction works. Construction industry in the past years has gone through a number of technological advancements relative to waterproofing systems (6). Though concrete is expected to be non-porous and free from voids and internal channels for seepage to pass through, there are properties of concrete which makes it susceptible to defects which may result in leakages in future (18). Due to properties such as low tensile strength and ductility, the concrete is prone to defects such as shrinkage cracks, efflorescence, etc. (23). Concrete is found to be permeable when it comes in contact of water, which when travels through the pores. A continual exposure of concrete to this water makes it weak, which may later on break due to disintegration. Damage and destruction resulting in accidents caused due to fasted deterioration as a result of moisture can be prevented by stopping water leakages in buildings. Excess amount water if absorbed by a building results in not only the corrosion of structural reinforcement but also creates leakage problem, which thereby results in expansion of cracks and concrete spalling. This can be prevented by installing waterproofing membranes in leakage prone areas (24).Defects whether it is leakage or any

other construction defect results from errors had by various stakeholders in the process. The conversion to smart buildings is critical for the development of commercial structures (2) Leakage defects often arise due to non-consideration of necessary preventive measures against the probable concern. Poorly worded specifications and unclear designs often lead to lower construction quality (4). 58% of defects were caused by faulty design, 35% from operation and installation, 12% from poor materials and systems, and 11% from unexpected user requirements (20). Leakage defects can also be observed due to damages to waterproofing done or poor choice of materials resulting in low durability of the selected materials for waterproofing. Fair wear and tear accounted for 56% of all defects, while 20% were attributed to poor design decisions, and 20% resulted from materials and workmanship (22).Direct cause of leakages to be the poor quality of waterproofing processes in construction. Leakage defects not only create problems for the residents but also the related concerns to the construction firms (26). Leakages observed in apartments are resulting in a yearly rise in disputes (15).

2. Leakages as a concern and their causes

Leakage in buildings is an age old concern and had been often discussed regularly in a number of sources. Water leaks are traced by abnormal consumptions of water (1) in the areas of use such as swimming pools, water tanks, etc. Moisture problems in buildings lead to health concerns and decrease the durability of building as a whole (20). The importance of waterproofing to prevent leakages holds high priority due to the presence of properties in concrete such as porosity and external saturation of cement creating high chances of water percolation in structure thereby creating a need for additional waterproofing measures (17). In a comparative study of conventional and modern waterproofing techniques root cause of low durability of concrete is the presence of moisture (24).The micro cracks resulting due to the presence of deleterious substances in concrete often result in a porous concrete product. Dryness of structure is a basic requirement of buildings, which if not achieved results in non-habitable and unsafe conditions for residents(19).Leakage problem is a source for a number of other concerns such as ceiling damages, mould and mildew development, etc resulting in health issues. Fire hazards resulting by water damage, compromises structural integrity of buildings, strength of concrete and reinforcement corrosion (25).The causes of staining in rendered walls results due to different moisture problems and related defects such as ground water, rainwater, etc. (11). The complex mechanism of building construction process and sub-standard technology for construction gives rise to seepage channels at outer face of building, which becomes more serious as time passes (12). The results of leakage starts appearing in new buildings after a period of use such as wall stains, painting surface peeling off, etc. Concrete being a porous material absorbs water and relative contaminants (3). It was emphasized that the leakage problem involves high-end theoretical knowledge and includes large repair and rectification costs with respect to materials, manpower, etc., thereby adding inconvenience to residents. Many problems exist in building waterproofing such as material quality is not satisfactory (9). Water leakages are considered a highly critical concern having a double impact including threat to health, hygiene and livelihood of residents as well inducing corrosion problems to the structural reinforcement. The last thing any resident would want to experience is water dripping from the roof ceilings of upper floors (10). One of the major causes for such leakages is the waterproofing membrane failures. The fast pace of construction execution often has many negative impacts due to the high speed requirements such as poor supervision, which results in leakage defects in future (27).

2.1Types of Leakages

Different types of leakages are as shown in fig. 1

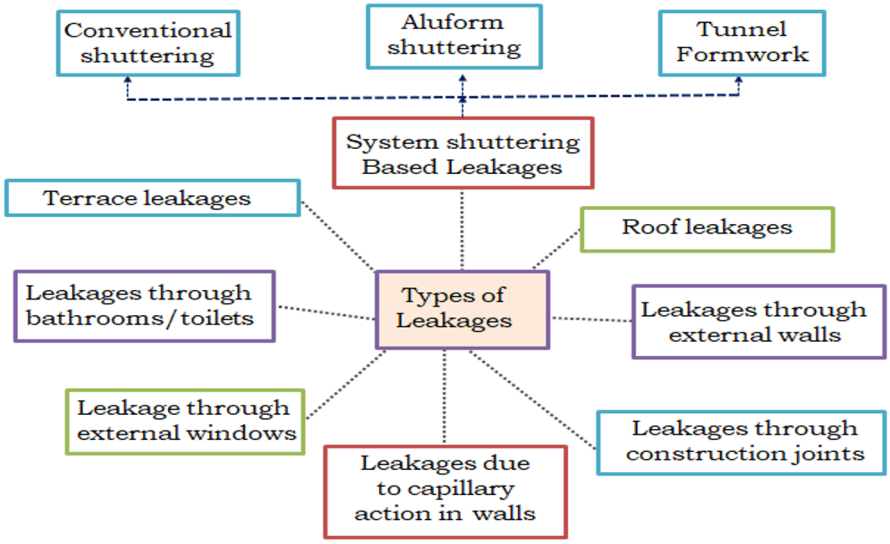

Fig.1 Types of Leakages

Terrace and roof Leakages: Terrace leakages results from shrinkage cracks, construction joints, and hollow pockets left in sunks, etc. left unattended at the time of slab casting. Rainwater or water from other sources when stagnated at area then results in leakages through terraces. Such type of leakages is very critical because they directly affect the top floor customers and leakages may even be as greater as continuous dripping water.

Fig. 2 Terrace and Roof Leakages

External Wall Leakages: If the exterior walls of a flat have cracks or gaps, water can infiltrate during rainfall. This can lead to dampness, mold growth, or water seepage on the internal walls. These leakages majorly arise in case of Aluform/ Mivan or Tunnel formwork system where excess wall tie/conic tie openings are available. Such openings if not packed properly at RCC repairing stage results in rainwater seeping and percolating inside common areas and flat of building.

Fig. 3 External Wall Leakages

Leakages through Construction Joints in External Faces: These leakages occur when the RCC construction joint at external wall is weak and no treatment had been done over it to overcome such issues. Leakages also causing damage to structural members (5).

Formwork systems like Tunnel formwork has a typical methodology of primary-secondary construction where extra waterproofing measures should be provided to prevent leakage from areas

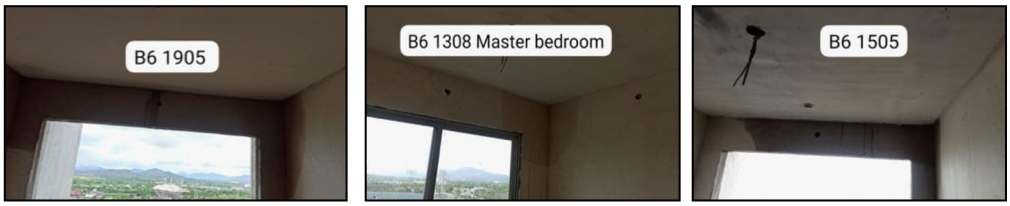

Fig. 4 External construction Joint Leakages

External Window Leakages: These leakages occur at times of heavy or moderate rains from external windows by water leaking from window sides or even tracks. They may result in damage of internal paints, debonding of floor tiles or even flooding in area which could lead to roof leakage in flat below. Photographic representation and examples of leakages through external windows for easy identification of observed problem,

Fig. 5 External Window Leakages

Leakages through Toilets and Bathrooms: Toilet and bathrooms are highly susceptible to leakage problems. They are considered to be wet areas because of continuous use and contact with water. This water if leaked may percolate to other areas including adjoining wall or floor below and cause major problems such as customer conflicts, peeling of and contamination of wall paints, false ceilings, etc. Consequently, identifying the segments of the network and exact leaking pipelines connected to these segments are challenging (13).Multi-label classification methods can be used for leak detection in pipelines (14).Photographic representation and examples of leakages through toilets and bathrooms for easy identification of observed problem,

Fig. 6 Leakages through Toilets and Bathrooms

Water leakage through car parking roof: These are the leakages from roofs of MLCP's (multi-level car parking) arising due to problems such as stagnant water, car washing at above floors, etc. Such leakages result in problems such as stains on cars due to continuous dripping water and often results in parking space related conflicts.

Fig. 7 Water leakage through car parking roof

2.2 Types of Waterproofing and Related Materials Available In Industry

In the era of a competitive market, there are a number of manufacturers with their specific materials related to waterproofing and concerned processes. It is very important to select particular material with respect to the location and methodology of use for any waterproofing system to be durable. Poor choice of materials may result in waterproofing failures, which is often associated with high repair costs. This poor or wrong choice of materials for waterproofing activities may be as a result of cost cutting measures, lack of budgets for concerned activity or simple due to lack of awareness in the concerned working professionals. There are waterproofing materials as liquid applied membranes for areas such as toilets, top terraces, balconies etc. Liquid applied membranes are further classified into different types such as, cementitious based, Poly-Urethane or Poly-Urea based, Acrylic Elastomeric, modified bitumen etc. Solid membranes in sheet form such as SBS and HDPE are mostly used for underground structures such as footings, rafts, retaining walls, etc.
In addition to waterproofing products, there are a number of materials which are associated with various process linked to waterproofing, such as, injection grouts for cracks treatment, non-shrink repair grouts, micro-concrete, poly-propylene fibres, integral waterproofing compounds, etc. These materials are used for process enhancement, strengthening or simple as part of the standard methodology. Different waterproofing and associated materials with their uses at different locations as leakage prevention and waterproofing measures are mentioned below.

Table No. 1 Leakages, root causes and preventions

Sr. No	Type of Leakage	Preventive measures
1	Top terrace leakages	Shrinkage and other cracks treatment to mother slab through pressure grouting or standard crack repair methods, construction joints treatment, terrace waterproofing treatment through standard materials (PU + Brick Bat Coba), slab ponding inspection at construction stages
2	Roof leakages	Hollow pockets and RCC defects treatment with specific materials, provision of spacers in floor tiling, Shrinkage and other cracks treatment to mother slab through pressure grouting or standard crack repair methods
3	Toilet/Bathroom leakages	Standard waterproofing treatment (PU/Elastomeric Cementitious/Acrylic/modified bitumen, etc.), provision of tile spacers with epoxy group provision, wall waterproofing till shower area, following standard waterproofing methodology

4	External wall leakages	Rectification and closure of openings such as wall ties, tie rod and other openings resulting from shuttering types, with specific method and materials (non-shrink grouts/gun graded non-shrink grouts, etc.), inclusion of waterproof coats for leakage prone opening areas (wall tie/conic openings), using waterproofing compounds in external and internal plasters on dead walls, selecting weather proof exterior paints and processes
5	External window leakages	Leaving sufficient gap between window frame and adjoining surfaces for sealant packing, proper packing of gaps between window frames and wall by proper weather proof sealants, provision of effective drain slots in windows and their verification at construction stage, leakage inspection for external windows in installation stages and treatment for any leakages observed
6	Leakages from car parking roofs	Construction joint treatments through standard methodology, selecting water resistant flooring systems such as PU/Epoxy based floorings, standard waterproofing treatments for car parking top terraces (PU + Sandwiched geo-textile + Brick Bat Coba
7	Leakage through capillary rise of water in internal walls	Provision of micro-concrete threshold bands in toilet waterproofing systems, provision of RCC/concrete layers as first course of wall masonry, provision of spacers with epoxy grout in floor tiles for toilets and other areas, provision of waterproof anti-capillary coatings at junction of floor and walls
8	Leakages through wall/floor in projects with conventional shuttering system	Construction joint treatments, proper treatment of openings such as tie rod holes, concrete joints, etc. by specific material and processes
9	Leakages in projects with Aluform shuttering systems	Wall tie openings through gun-graded non-shrink grouts, packing of sunken frame ties through non-shrink grouts, eliminating AAC block work/brickwork at external faces, using waterproofing additives in external plasters, incorporation of pre-texture DPC, weather proof exterior paints, and moisture resistant internal plastering material for dead walls/exterior walls.
10	Leakages in projects with Tunnel formwork systems	Packing of conic tie and kicker leg openings through non-shrink repair materials, eliminating block works in external faces, using waterproofing mortars for external plasters, incorporation of pre-texture DPC, weather proof exterior paints, and moisture resistant internal plastering material for dead walls/exterior walls, incorporation of separate waterproofing system for primary and secondary construction joints

3. Steps for a Robust Waterproofing System

Waterproofing activities have been recognized throughout the industry as one of the most critical activities in construction prone to failures and customer dissatisfaction. It has been very commonly observed in construction projects, that despite of using standard

waterproofing materials, the system results to be a failure in terms of leakage appearing or re-occurrences thereby questioning the durability of system. Standard usage and work sequence activities are often neglected due to lack of knowledge, awareness or simply carelessness by site professionals to achieve fast construction progress of reduces process cost. However, this negligence in following necessary steps and sequences could be a potential root cause of waterproofing system failure.

a. Surface preparation includes general RCC repairs, surface grindings and touch-ups in order to make surface smooth and ready for coating, attending any visually observed cracks by standard material and process, removal of unwanted materials such as oil, greese, slurry, curing compounds, any holes and openings to be closed by standard material and method, dust and debris from surface to be washed or removed.

b. Plumbing and electrical works clearance to be taken before starting of waterproofing works in order to prevent puncturing of waterproofing membrane through screws and fixtures. Plumber also needs to fix sleeves for pipes as per requirements of slope and further works.

c. Coving/Wata/Re-profiling from mortar admixed with integral waterproofing compound and poly-propylene fibres to be done at junctions of vertical and horizontal members. Standard bonding agent to be used for proper adhesion of coving/wata at floor and wall. 10mm aggregates could be additionally embedded into mortar of coving/ wata.

d. Core packing / Bore Packing - Closure of vertical/horizontal plumbing openings wherever applicable, such as toilets, balconies, etc. This shall be done by standard micro-concrete material having non-shrinkable properties and having strength one grade higher than grade of base concrete. It shall be noted that plumbing pipes when fixed in cores shall be roughened by suitable means and applied with standard PVC material compatible bonding agent sprinkled with sand over it in order to create a mechanical key for bonding of core packing micro-concrete and plumbing PVC pipe. In addition, inside surface of core cut area shall be treated with old to new concrete bonding agent chemical. Focus shall be given for proper shuttering from bottom for core packing, thereby facilitating packing for material throughout core depth with respect to slab thickness.

e. Bare Slab/Mother Concrete ponding/leakage inspection is very important and should not be eliminated from sequence. The significance of base concrete ponding/leakage inspection is to ensure that bade concrete or mother slab is free from any leakages the waterproofing system to be done above is an additional measure for long term durability of building unit waterproofing waterproofing system. Generally, this stage ponding is done for 24 to 48 hours or as per requirement and criticality of situation.

f. Application of primer wherever applicable with respect to product technical data sheet and requirements for main waterproofing membrane.

g. Application of two coats of main waterproofing membrane on prepared surface specific to location such as single/dual component liquid applied membranes for toilets, balconies, water-tanks, etc. HDPE membranes for underground structures such as rafts and footings, SBS membranes for vertical structures such as retaining walls, swimming pool external wall face, food grade epoxy coatings for OHT Tanks, coal tar coatings for STP tanks, etc. It shall be noted that technical data sheet (TDS) as incorporated by product manufacturing company of each product should be referred for its effective use. Number of coats for liquid

applied waterproofing systems should be decided with respect to required dry film thickness (DFT) for effective applicability and durability.

h. Extra Precaution for core packing area - Since this area is highly susceptible to waterproofing failures and leakages, extra precaution is recommended in the form of geo-textile fabric sandwiched between both coats of main waterproofing membrane.

i. After coating ponding in case of toilets, balconies and other confined areas is done generally for 48 to 72 hours in order to cross-check for any minor leakage arising due to any reason that could be treated and arrested by rectification or modification of coating being done, so that any reworks are avoided in case when leakage is observed in final stage ponding.

j. Provision of adequate protection for the waterproofing membrane and coatings,due to multiple construction activities going on in building area under construction or repairs simultaneously, there are high chances for waterproofing membranes to get damaged by moving workmen, machinery or materials. Thus, adequateprotection in different forms is given to waterproofing membranes and coatings for their efficacy and durability. These protections are specific to the type of waterproofing system such as dimple board/protection sheet application for vertical waterproofing membranes, screening with concrete or mortar admixed with suitable IWP (integral waterproofing compound) in required thickness. The protection screed is also admixed with poly-propylene fibres for strength and cracks prevention.

k. Final ponding and waterproofing effectiveness verification is final stage in waterproofing methodology in order to verify whether the waterproofing system is effective in retaining water or not. For toilets, balconies, OHT's (overhead water tanks), and other confined spaces where ponding and water retention could be made and leakages observed could be identified, ponding is done for 7 days and inspection is done for any leakage observed. In case of vertical structures such as retaining walls, water shower test can be done for any leakage observed from other end. In case of underground structures where visibility from other end is not possible for leakage inspection, water retention and loss of quantity/water drop can be verified in order to check the leakages.

3.1 Sectional Drawing for Typical Toilet Waterproofing

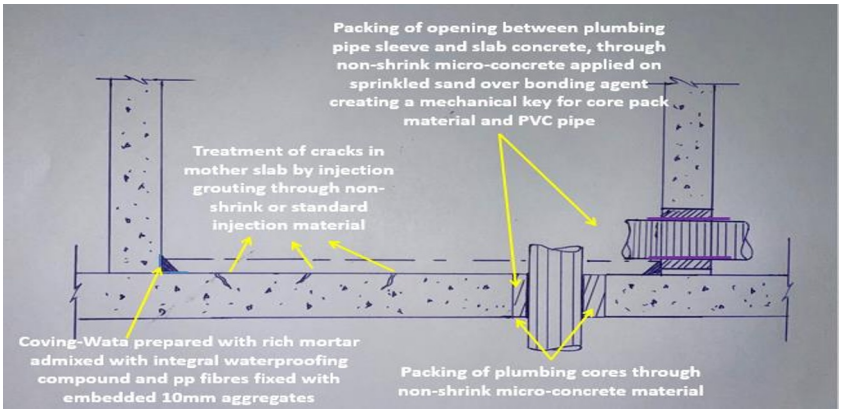

Fig. 7.a Sectional Drawing for Typical Toilet Waterproofing

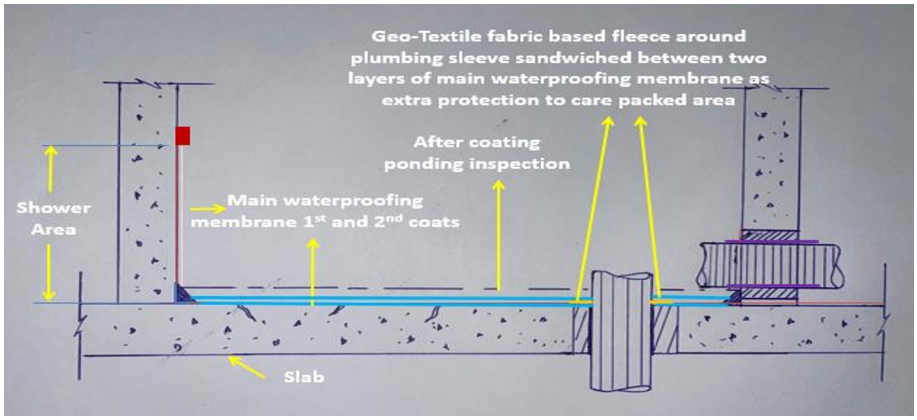

Fig. 7.b Sectional Drawing for Typical Toilet Waterproofing

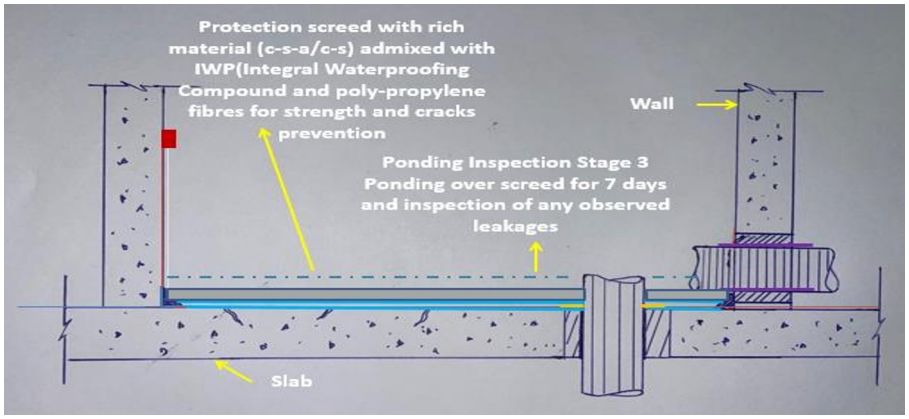

Fig. 7.c Sectional Drawing for Typical Toilet Waterproofing

4. Conclusion:

Different types of leakages were listed in report on behalf of data collected from leakage concerns observed in residential flats situated at different locations of Pune and other data as per concerns from real life customers. Preventive measures were recommended which could result in mitigation or elimination of any possible leakages from the different sources and locations. Waterproofing failures are also major reasons of observed leakages in high-rise buildings due to faulty workmanship, poor adherence to standards and violation of work sequences. Standard work sequence and step wise procedure along with recommended materials is presented in study, adherence to which results in a durable waterproofing system.

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