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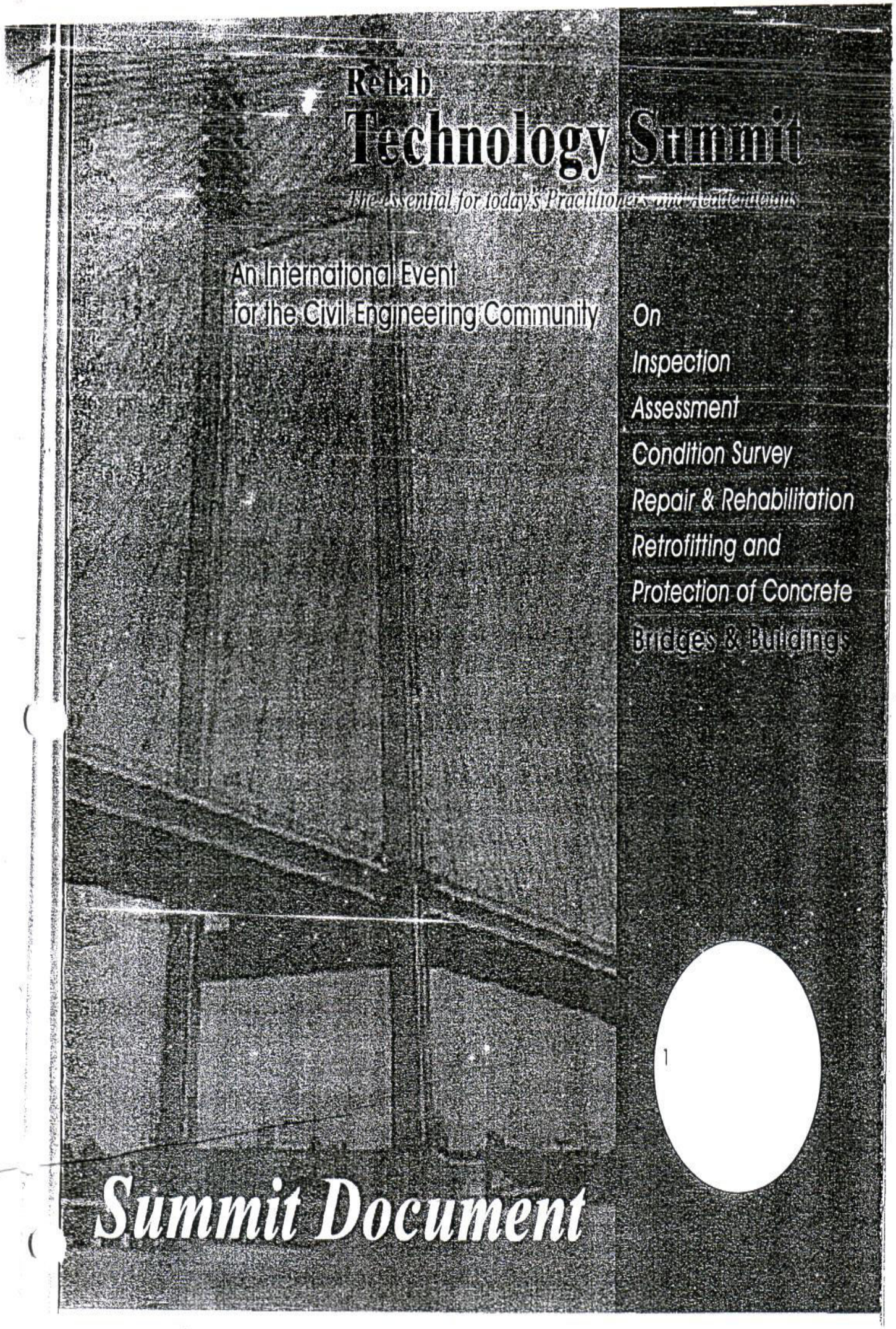
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INTEGRAL & SURFACE PERMEABILITY REDUCERS & ELIMINATORS- PRODUCT SELECTION CRITERIA

By Jatin Ambani.

Waterproofing of buildings and other concrete structure had been the most troublesome yet the most neglected portion of civil engineering particularly during construction stage. Most of the time, leakage problem is bought to the notice of manufacture & applicators only when the problem starts and aggravates. There has been lot of reluctance towards preventive water proofing, right at the construction finishing stage. Unlike exclusive elevation and expensive interiors, very less budge provision is made for water proofing treatment. Now, with changing trends, it is interesting to note that waterproofing is treated as one of the important aspects whereon all concerned is contributing serious sly. Consultant by detailed specification and manufacturers by producing innovative products and providing right application methodology, tailor made for a given problem.

Need of waterproofing products: Root causes.

Ideally, concrete the most widely& regularly used construction material is supposed to be water tight with co efficient of hydraulic permeability between 10-8 to 10-10 m\sec. A well made concrete with proper mix design and proper pouring and curing practice is regarded as very low porous material. However, it is seen in practice that concrete and renders looses its impermeability due to:-

1. Improper gradation of ingredients.
2. Excessive water cement ratio.
3. Less/Improper compaction.
4. Awkward architectural shaped section.
5. Improper shuttering materials & practices-
6. Cold joint in concrete either in mass concreting or in tall vertical structures.
7. Use of bad qualities construction material such as corrosive reinforcement or reactive aggregates.
8. Lack of curing, particularly in high cement content concrete mix or where high grade cement is used in plastering.
9. Damage to structures due to earthquake effects/ fire / storm natural calamities
10. Failure of plumbing.

Typical problems are faced in north Eastern regions where brick bats are in use as coarse aggregates & such a highly porous material causes leakage problem. I! is also observed that leakage problems are accute in high humidity areas where water penetration problems. It is also observed that leakage problems are accute in high humidity areas where water penetration process is always on due to capillary action from atmosphere to unsaturated concrete. Water penetration can also take place due to hydrostatic pressure in major water retaining structures like E.S.R. raw water reservoirs, water treatment plants and so on.

Thus above prevailing and unavoidable circumstances creates necessity of good

WATERPROOFING PRODUCTS.

Waterproofing Products Available in India and its usage:

A. DURING CONSTRUCTION STAGE:

1) Concrete Admixtures:

They are better known as plasticizers / water reducers. They work on principle of either reduction of surface tension or few products act as blockers of space created due to uneven particle size distribution..

Many of the concrete plasticiser and super plasticiser complying to IS-9103 act as water reducing agents thus reduce permeability of concrete and also comply with IS 2645 requirements, at reduced W/C ratio.

2) Integral Waterproofing:

Available powers as well as liquid from, integral water proofing compounds are the most popular and commonly used products. Here, power waterproofing is to be mixed with neat cement, which subsequent by will be used for products. Here, powder water profess is to be mixed with neat cement, which subsequent by will be used for preparing mortar or concrete liquid water proffer is to be misud with dosing water which can be used in cement mix or dry concrete mix.

Such compound will be effective only when w/c ration is controlled and proper inter locking of ingredients of concrete is observed to get a cohesive mix based on particle size distribution, while designing concrete mix.

B POST CONSTRUCTION STAGE:

Crack Filling:

Depending on size, shape& nature of crack suitable product is suggested Few Hydraulicatty fast setting non-shrink powder is used after widening Hairline cracks and making 'V groove. Water is added for obtaining trowel Able consistency & crack is filled with gloved palm or

- steel Patti. This Product is also used for plug giving running leakage from water tank, RCC Hume pipe ect. And can be used underwater in fully submerged Condition.

Liquid acrylic flexible crack sealer can be used where thermal stresses are high and crack tends to expanded and contract such products are user friendly and can be used by anybody without any hiteach, without any special tool-tackles

Expansion joint treatment:

Polysulphide silicone or polysurethane sealant are in use depending upon

Specification and users preference. Polysulphide is grey in colour while Silicone sealant is either colourless or white PU can made available in few selective colours .most important property here is accommodation factor.

Size of expansion joint and distance of joint is desing aspect and is in perview of consulting engineers. Hower ever, correct joint preparation and application methodology here is of utmost importance.

WATERPROOFING COATING:

Depending on basic materals, waterproofing coatings can be divided in to following types.

(a) Silicate based penetrating type single componety powder e.g. Fucoseal.

(b) Polymer modified two component brush applied coatings.

(c) High polymeric two compoent brush/trowel applied flexible UV stable coatings..

(d) Single component highly elastic liquid coatings

(e) Epoxy or polymerethene coatings.

Due to its moisture sensitive nature, epoxy & PU coatings have not become very popular. Care should be taken to protect the coating against mechanical damage using screed or plaster on top of it. Coating can fail if proper surface preparation practice is not observed. Manufacturer's recommendations must be followed religiously.

EXTERIOR WATER REPELLENT COAT INGS:

Silicone based colourless coatings are applied on exterior face of buildings for-

- Protection against salt efforance formation
- Prevention against growth of algi or fungus
- Prevention of water, seepage through hairline crack in external plaster.

Protection of exterior paint for long duration.

Silicon water repellents are of two types.

1. Water based-having lesser life span.

2. Slovent based-having life of 5 to 7 years.

Silicone water peller is very cost effective solution which can be applied on various substrate such as bricks, stone, cement, paint, stone cladding and many more.

BITUMENOUS FELTS & POLYMERIC BITUMENOUS SYSTEMS:

-Very popular as five layer and seven layer treatments this system started given problems this started given problems at few place since 1970 due to quality problems of straight grade bitumen as a result of setting up of propane deasphalting units at refineries. This has led to necessity of introduction of polymermodified bitumen. Torch on APR modified membrane system with nonwoven polyster reinforcement and pour& Roll/joints torched membrance system are also becoming popular. Reinforcement material to membranc has varieties like glass /carbon fibers too.

a) Brickbat Koba:

The most widely used conventional waterproofing system since decades has stared being replaced by chemical waterproofing due to higher dead load on structure and inability of application on vertical surface and odd shaped structural members, very high material handling and limited yield in terms of productivity affecting speed of the job.

It was also observed that while removing 10 to 15 years old brick bat koba system, basic concrete structure was disintegrated. This might be due to soaking of water by clay in brickbats and transferring the moisture in pores of concrete causing corrosion of reinforcement. In spite of all odds, this system is still in use for in use forgiving slope on terrace protecting chemical coarings from UV and mechanical damage for water proofing.

b) Concrete Bonding Agents & Grount Additives:

During construction of E.S.R.,E.T.P. or other Water retaining structures, old joints in concrete are bound to came between each lift of shuttering For bonding already set concrete and newly poured concrete, epoxy or rubber based bonding agents (e.g.ECU-352 or SBR Latex) must be used. This practice is hardly' following at site resulting in to leakage through cold joints of concrete. Also when harsh unworkable concrete is poured in to the structure, especially in conjusted reinforcement, honeycombing in concrete gives a way to eater percolation. Problem is also created at times at times due to improper placement at PVC rubber stop in concrete joints.

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To overcome such problems neat cement slurry with expansive with expansive grout additive (e.g.Shaligrout IP) is injected in body of concrete after drilling hole and fixing nozzle. This additive helps cement slurry to travel more in capilaryn path and also to compensate for shrinkage at cement.

c) **Very Fine Permeability Reducers:**

Lime stone, ground sayed, bentonite, whiting, PFA, diatomaceous earth, colloidal silica fumes and fluorosilicates are finally divided materials having pozzolanic reactivity thus densifying cement gel matrix by replacement of course cao h2 crystals with gel like hydrated calcium silica products, which blocks the prose & help in reducing permeability thus indirectly works as water proofing aids.

Aspects to be considered for Product selection:

Flowing are the types of structures requiring barriers for water ingress:

- Flat structures like R.C.C. slab /Weather shed. Or sloping structures like roof.
- Above ground or under ground structures.
- Internal / external i.e. in context of Ultra violet ray stability.
- Water pour facing or water retaining structures
- Exposed to rain facing direction or covered under cantilever projection.

Questions & classifications are many & answer changes every time. There is nothing called an absolute truth in waterproofing situations. An answer which is right at one place may prove to be wrong at another one, may be everything else being right except just a change of geographical location. An expert eye with due experience of varied nature only can lead to the right solution. Questions like permeability of cover concrete & difference between permeability reduction & waterproofing / seepage control still remain debatable.

CONCLUSION:

Waterproofing is very vast subject to discuss and describe and every water proofing problem has to have tailor - made solution. From the products described above and also from few other undescribed ones, innovative solution is to be sought in a given situation.

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Jatin Ambani

Protective Coatings for Concrete - Today's Scenario

Mr. Jatin Ambani is a civil engineer with management qualification and long successful track record in field of construction chemicals & its applications. He is involved in consultancy & execution of projects in field of structural repairs, waterproofing, industrial flooring. Over & above contracting at various parts of India, he has continues involvement in traning & development of civil engineering professionals during his corporate as well as business career.

Reinforced cement concrete popularly known as RCC is modern material which placed many old construction materials & could attain popularity by virtue of its versatility & simplicity of pouring it to different shapes & sizes with height no bar. However, unlike ancient stone structures having proven track record of life cycle, durability is a real threat to concrete's long lived popularity. Developments in modern world structures were promptly contributed by concrete in its various forms.

Following are major root cause for concrete to decay/ deteriorate/ decrease its expected life.

' Ingress of chloride ions from concrete cover zone to reinforcement, particularly in' marine environment having higher humidity level. '

* Sub soil sulphates causing damage to foundations & underground structures.

« Emission of carbon dioxide affecting areas near heavy vehicular traffic.

* Water vapor entering concrete through porous cover zone capillaries.

« Separation cracks in buildings between R.C.C. & masonry due to *its* different co efficient of thermal expansion.

* Physical reasons like impact, abrasion, erosion.

« Biological reasons like growth of fungus, algae, vegetation etc.

* Usage of improper ingredients constituting concrete i.e. sand, aggregates & water.

Role of Protective Coatings

It is strongly believed that concrete behave like a human being barring emotions. It always shows its illness & agony against its misuse by showing different signs of distress. It requires an expert eye to really understand its language by talking to a structure. That necessarily means that selection criteria of a protective coating suiting to site requirements needs in depth knowledge of concrete technology & material chemistry.

Protective coatings must be viewed as performance enhancers of concrete in terms of its expected life cycle by delaying ageing process. No do not relieve an engineer to keep away from good concreting practices. How ever, it must be mentioned that many limitations of concrete are supplemented by protective coating by providing few properties where concrete lack performance. Protective coatings are suppose to play vital role in situations like:

* Marine environment structures.

« Concrete structures facing Chemical fumes / spillages.

* Aged structures awaiting treatments to restore damages.

« 111 designed structures at lesser than codal provisions having premature distress.

• * Composite structures having different materials with different behavior in given climatic conditions.

» Structures situated in areas having large variation in daily & seasonal temperature

* Structures situated in areas of heavy rainfall or continuous vibrations (e.g. buildings near railway tracks) or even change of proposed usage than the designed one.

Requirements of Protective Coatings

Protective coating shall not merely be viewed as corrosion fighters but can also be expected to combat permeability & cracking due to thermal stresses. At different site situations, coating must possess few properties as listed below.

* Ability to prevent ingress of water, chlorides, sulphate, CO2, Vapor etc.

* Crack bridging capacity.

* Excellent adhesion to substrate.

* Water repellency & sacrificial layer for dust resistance.

* Over coating compatibility to various primers & top coats.

* Reasonable pot life & dry time.

• Stability against Ultra violet rays.

* Color stability in case of pigmented coatings.

» Penetration to substrate / top cover zone.

• Resistance to fungus & algae growth & salt efflorescc protrusion.

. Potability of food related products during storage.

All the coatings do not necessarily possess all above, properties. Even the requirements changes from site to site.

Types of Protective Coatings

Protective coatings can be categorized as below depending on usage of raw materials.

* Pure Epoxy or Novolac resin two component
• Polyurethane two component
* Pure Acrylate dispersion or co polymer base.
* Styrene butadiene rubber base.
* Epoxy polysulphide blend.'
* Coal tar epoxy or bituminous urethane.

Spray application of lower viscous counting on horizontal surface gives deeper penetrating in concreted pores with better coverage and speedy output

* Polymerized bitumen base.
* Silanc/ Siloxane or Silane siloxane blend.
* Polymethyle methacrylate (PMMA)
* Pliolite resin base
* Cement based polymer modified single or dual component coatings and many other formulations.

Depending on carrier used, protective coatings can further be categorized as:

Water based or solvent based.

However, usage of sol vents like toluene, acetone or other thinners is banned in many developed & environment conscious countries because it contain V.O.C. (Volatile ORGANIC Compounds). Also water vapor transmission in most of solvented T coatings had been in question thus it causes problems related to durability of coating system.

Limitations/ Defects in Coating System.

• Failure of adhesion to substrate due to either disproportionate mixing of two components or incompatibility of resin to substrate.

• Failure in expansion/ contraction cracking:

• "Fish eye" due to moisture insensitivity of resin.

* Blistering due to nonbreathability.

* Discoloration due to U.V. instability of pigments used.

* Disintegration of film due to instability of resin to U.V.

* Insufficient surface preparation resulting in peel off / debonding

* Transformation of color / smell to ingredient in physical contact

Testing of Coating Systems:

* Central Food & Technological Research Institute. Banglore (CFTRI) for Potable water/ food grain contact related tests.

* Indian Institute Of Chemical Technology. Hydrabad. For tests related to acid/alkali resistance of coarings.

* Central Institute Of Plastic Engineering & Technology Chennai & Ahmedabad. (CIPET) for tests like fire ratings, Co efficient of thermal expansion (Linear), bond strength, Shrinkage resistance, Elasticity modulus etc.

* Indian Institute of Packaging. Mumbai for tests like salt spray (Showing weather resistance). Bond strength, abrasion resistance, adhesion strength etc_

* Central Electrochemical Research Institute (CECRI) Karaikudi & Central Building Research Institute (CBRI) Roorkee are involved in innovating various coating systems suitable for long term protection of concrete structures.

Many other reputed laboratories like Indian I'^' : .-ii- ••:technology at various locations, structuragineeringresearchInstitute(SERC), Chenni renowned engineering co lleges & many solids, pH value, water absorption, specific gravity. Viscosity on Rotationviscometer, coverage on various surface, wet and dry film thickness, flash point, pot life after mixing at specific temperature etc. on protective coatings.

Infrared spectrum using IR Spectrometer, thermogravimetric analysis to measure binder component to ensure adhesion property, elongation at tear etc. are few advance testings of coatings. Important properties like weathering resistance due chloride ions and Carbon dioxide penetration are tested at Germany or U.K. at Taywood or Engelfreid methods.

Various standards like IS (Indian Standards), BS (British Standards), ASTM (American Standards for Testing of Materials), EN (European Norms), DIN (German Standards) are followed for testing such protective coatings.

Protective Coating Selection Criteria.

Manufacturer recommendation should be a prime concern in selecting coatings for RC.C. or masonry coatings. However, there are few generic properties of products which can narrow down selection process out of wide spectrum of products available. Following are the listed Strengths & weaknesses

Epoxy resin based products are suppose to have good chemical resistance. Particularly amine cured systems are good resistant to alkalies but acid resistant is limited (Good in novolac epoxies) and solvent resistance is poor. Surface need to be dry for effective adhesion. They are widely used at petrochemical, fertilizer & chemical related industries, on both steel & concrete. Water based formulations are popular in food & pharmaceutical industries because of god resistance to fungal & bacterial growth. U.V. instability is the biggest limitation for selecting such wonderful material for external applications. Polysulphide resin is blended with epoxy to improve this property but track record is seldom available.

Polyurethane like epoxies has good chemical resistance & bonding. It has better U.V. stability but lack moisture sensitivity so surface has to be bone dry for effective results. They are used in various applications of floorings, coatings or waterproofing, some times by blending mastic.

4. 3-way fiberglass strand reinforcement
5. Copolymer/ Bituminous adhesive
6. 99.9% Pure polished Aluminium Foil

Component Functions

Aluminum Foil Reflects heat by at least 95% (Top side). Resists water vapor and prevents water penetration. Rust-free. Kraft Provides structural strength for the aluminum sheet. Bitumen serves as bonding agent to the components while giving waterproofing characteristics to the sheet. Polyethylene provides the foil resistance to scuff and seals minute holes

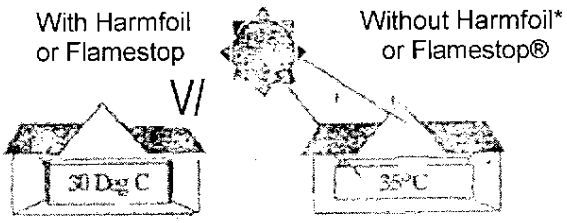
And cracks in the aluminum foil. Glass fiber is used as reinforcement scrim to prevent sagging and stretching of the sheet and to provide multidirectional strength. Aluminum foil doubly guarantees heat reflectivity of the sheet. (Top & Bottom sides)

Harvi-Foil is also an Excellent Roof Undersheeting

Harvi-Foil is used effectively not only as an insulating material but also as an under sheeting for roof tiles to serve the purpose of a impermeable secondary roof that not only takes care of the waterproofing but also the radiant heat barrier. It used to be that tiled roofing system needed metal under sheeting and a separate insulation material. Now, for the price of one, you get an insulation material and effective aluminium under sheeting that is moisture-proof, rust-free & longer lasting. So perfect for any buildings, and even for those in the coastal regions.

Flamestop® and Harvi-Foil® not only contribute to energy conservation but also provide a more comfortable living and work environment, extremely safe to handle and human & eco-friendly product. It

BENEFITS OF ROOF INSULATION
Ambient temp 30°C and roof temp 39°C



maintains the internal room temperature, almost at the same level as the ambient temperature without any energy costs. The use of radiant heat barriers for thermal insulation has been approved by ASTM, BS, BRANZ PSB Corporation, etc. It outperforms the conventional absorption based systems in use for thermal insulation in overall thermal performance, hygiene, energy conservation, durability, cost, vapour barrier effect and had various secondary benefits like roof under-sheeting, light reflector, easy installation, payback etc.,

More details on some of the world's best insulation systems, concrete protection technologies, and heritage preservation techniques are readily available with the importers, distributors &. technical implementers:

Bison Shelter System Pvt Ltd.,
Racal Towers, 35/984, Janatha Jn;
Palarivattom, Cochin - 682 025
Tel: 91 484 2344001,.
Fax: 91 484 2342941,
E-mail: bisons@sify.com

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Acrylic or styrene based coatings are generally breathable in nature & are used widely as

Decorative cum protective coatings on building walls, terraces or even water retaining structures. Some times, they are used in conjunction with cement as modifiers to improve up on properties of cement for adhesion, flexibility, water resistance etc.

Silicone/ Silane / Siloxane based coatings are having water repellent properties & are available in water based / solvent based / mineral oil based formulations. They penetrate in porous layer up to 3 to 5 mm & some times act as a primer to acrylic paints or to coat to cement paints. How ever, the life is found to be limited but it goes well with its low installation cost.

Many types of filler materials like silica sand, titanium dioxide, metacaolin etc. are used in coatings either to increase its thickness or for pigmentation or even to enhance mechanical properties. Fibre reinforcement is used to increase tear resistance & crack bridging. There are continuous developments taking place in the field which makes few age old beliefs obsolete. Over a period of time, protective coatings have proved to be good at cost benefit ratio. Correct selection oi product & appropriate application method still. make protective coating a correct option to :•;.•• ;-.M >r.

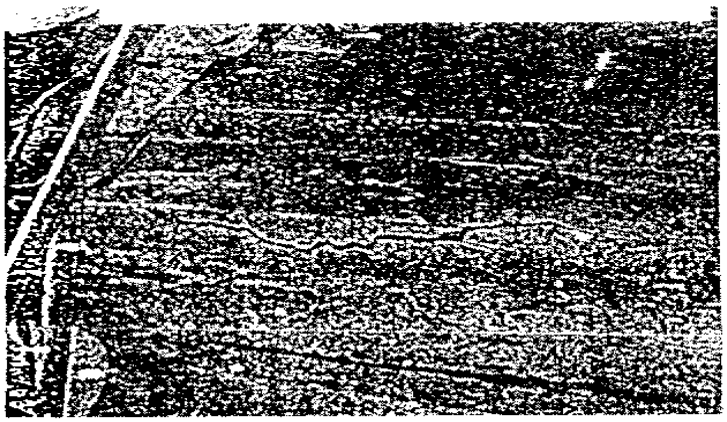
Jatin Ambani

Factors Leading to Building Repair & Berepair Situation

Buildings are brainchild of architects & R.C.C. designers which is created by meticulous planning on paper keeping in mind expected life of KM) years+ under guidance of various code of practices derived out of wonderful experience of prominent dignitaries of civil engineering fraternity. This dream is converted into reality by contracting agencies selected with due care with all techno commercial considerations. Thorough quality checks on materials & men are implemented at site to ascertain delivery of assumed quality for each item involved. Some how, it is seen that reality bites in many cases where structure start showing premature signs of distress right in its young age & needs life support system in terms of repairs.

Root Cause Detection for Defects During Conception Stage.

A child born weak remain unhealthy through out 'its life cycle & so a structure do. We talking of qualification in every part of our life i.e. a doctor need to be certified by medical council or even a nurse assisting him/ her need to have proper training & certification before they attend or cure patient. Unfortunately the same is not our view point while selecting a contractor. (Leave apart trained construction workers which is a dream far from reality). Cost becomes a qualifying criteria & quality which has thick relation with qualification / training takes a back seat. Why only private but also government contracts are decided on such nonqualified basis. Unlike All India Medical Council, there is no organized body to create awareness & fight for rights of civil engineers. Civil Contractor selection process in most cases is uncivilized & of the least importance. Consulting engineers / supervising agencies are expected to talk to contractors who seldom understand civil engineering language. Government squad to catch doctors practicing without certificate but award contracts of important civil engg. Structures to contractors without certification.



Root Cause Detection for Defects During Construction Stage.

When the actual execution starts, entire concentration from the day one remain more on progress of the work. Engineers start uttering words & showing concern on bar charts / C.P.M. / PERT & Q.C. / Q.A. dept. are kept at a hut like accom modation with very limited equipments & may be without experienced engineer. Following could be results of negligence towards structure like new born baby without tender care. Error of judgment from structural designer's side could also prove to be vital in deciding serviceable life of structure.

A) Material Quality Related Issues:

Aggregates contribute to the maximum in concrete in terms of weight & volume.

Flakiness index, elongation index & sediment residues(as per IS 2386 part 2 -1963) of aggregates from quarries play major role in concrete mix design. In spite taking all factors pertaining to coarse & fine aggregates in to consideration, porosity still prevail in concrete more or les, most of the time indispensable. The reason being sizes & shape of natural aggregates being natural & hardly much can be done about it Except taking due care in terms of their proportions in concrete matrix. Large difference in particle size distribution resulting due to availability of

reduced particle size of higher grade cement create what is known as particle si/.e interference. Gap graded concrete in spite all claims have not proved to be as effective as continuously graded concrete. No concrete with x.ero permeability could be achieved without voids / capillaries.

Less burnt bricks absorb lot of water thus lead to permeability & transferor moisture to adjoining R.C.C.. Such happening for a prolonged period of time end up resulting in to concrete distress.. Clay of salty nature become bad raw material for making of bricks. This is like having inherent defect which keep troubling throughout of structure's existence. Effloresce keep (lowing out every time, rectification of plaster/paint is done. Only remedy remain is to demolish & reconstruct using better quality masonry materials.

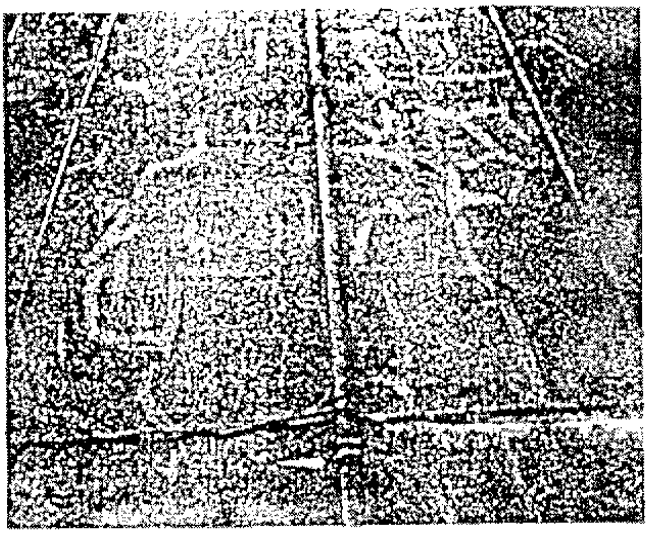
Sill/salt in fine aggregates create .problems like cracking / effloresce. Mechanical properties of aggregates like crushing value, impact value or abrasion value play major role in determining durability of concrete.

Reinforcement changed from mild steel to tor contributed to better mechanical bond of rebar to concrete but tor steel is more prone to corrosion a'.tack compared lo mild steel. Instead oi" using latest technique of migrating corrosion inhibitors as Additives lo concrete to combat rebar corrosion, costly treatment of fusion bonded epoxy tesin factor\ coated bars is in use at most of the major infrastructure projects.

Use of admixture even to day after 25+ years of its easy availability with good quality comparable to am international standards is considered as additional expense in making of concrete / mortar. Water is found 10 be better alternative in increasing workability" rather than using plasticizers. Such savings (perceived, not actual) lead to much higher expenses in costly repairs of structure during its lifecycle with inconvenience as bonus.

R) Workmanship Related Issues:

Fate of building under construction largely depend on workman contributing practically in activity of creation of structure. Lack of trained workmen play the biggest role in pushing structure towards its proposed repairs prematurely. Bad / insufficient mixing of ingredients lead to porosity. Bad pointing of brick work loosen bond between layers of masonry. Bad shuttering create concrete



with honey combs which is like having disabled structure with permanent deficiency. Training/skill is essential even in slacking brick pieces in staggered manner while doing terrace waterproofing in conventional manner. Art of laving china mosaic even to day is lying with few female workers & others trying the same without due proficiency proved to be unpleasant unacceptable work

Insufficient compaction of foundation soil either due to haste of pouring first batch of concrete or due to non availability of adequate compactors/ rollers lead to irreversible & non attendable problem of foundation settlement.

Lack of PROPER tools, tackles again play vital role. We are used to find locally available means to be adapted lo find on temporary solution / alternative to what is really required to do a good job. viz. Compaction vibrator replaced with iron rod / bamboo has given wide prospects to building repair industry. Bad quality shuttering material like absorbent wood / rotten" steel plates make rover concrete unable lo protect structure & fail to its purpose of existence.

Hacking of concrete to provide mechanical key to plaster/ render is widely seen phenomenon, which leads to micro crack generation in surrounding areas. Concrete / plaster bonding agents are not highly accepted by industry may be because after effect of such misbehavior with concrete is invisible with naked eyes & occurrence of problem is long term i.e. after years from completion of site.

Permeability of concrete / plastering morter particularly in cover zone leads .to entry2

deleterious gases /vapor leading to attack on reinforcement

Lack of curing leads to early age cracking of cementitious render/ concrete which become cause of concern at later stage. It also becomes visible evidence of. negligence of poor quality.

Root cause Detection for Defects During Life Cycle of Building:

Because of contributory factors mentioned above, structure will start showing deterioration "•signs. Barring ageing; many other signs of illness of structure are due to lack of conscious efforts to properly construct & timely maintain the building. As a result, cracks, erosion, leakages , dampness signs & spalling of cover concrete or even part of cantilever nonstructural member are alarming signals to opt for treatment to restore health back to normal.

A) Workmanship & Material/ Methodology Selection Related Issues During Repairs & Restoration:

Proper Diagnosis is as important as cure. To know reason for why it has happened is more important than !o merely quantifying of what has gone wrong with building. Survey & budgeting exercise should necessarily be done by ?. qualified & experienced personnel so as to ascertain treatment materials & method, which shall obviously expected to be tailor made.

Patch plaster selected as an option to chipping off full plaster should be border marked using cutter to avoid feather edging & micro cracking at neighboring areas-Use of PP fibre 12 mm long in first coat plaster & 6 mm long in 2nd coat plaster as transverse reinforcement can help reduce probable cracking. Bond coaj on R.C.C. & at edge of old to new render while plastering should be considered as essential & decent practice & this must be weighed while selecting contracting agency & be paid while executing.

Breaking while treating distressed structural member must be done around entire periphery of reinforcement bar so as to passivate corrosion of rebar in totality. Shuttering for jacketing of column beam must be leak proof or else cement slurry or low particle sized micro concrete may flow out defeating purpose of alkaline protection & uniform load distribution.

It has also been fashion to adopt latest technologies like fiber wrapping without due design considerations or some times even without necessity of structure, just to try out at risk & cost of clients. Same applies to addition of micro silica which is added to mortar in the name of permeability reduction which some times add to cracking of mortar due to lack of cohesion. Selection of nylon fibers in place of P.P. or wrong sized fiber usage due to non variability of right length material at siterloes no good & rather become harmful. Polymer dosage in making of PMM varies from 5 % to 20% & client or even contractor gets confused .Thermal stress Crack cutting at many sites is done using chisel hammer & filled with cement mortar thus creating two cracks at both edges of crack over & above making defective area very wide. Galvanized Iron pipes used for water distribution corrode from outside at loop level as well as connector wall pieces from tank outlet, parapet & inlet to dwelling unit's bath? kitchen because of lesser galvanizing thickness. Inner corrosion of G.I. reduces effective water carrying capacity & reduces flow force. P.V.C. sleeve around wall pieces & use of UPVC pipes, if net copper plumbing proves to be value for money decision.

B) Issues Related to III Maintenance & Abuse by Residents:

Structures are disregarded the most by none other than its owners & occupants. In places like metro cities where every inch of space counts, fascination of covering cantilever structures like balcony & putting it to usage of storage / goods stacking is irresistible. Lakhs of rupees are spent by individuals in interior decoration but when it comes to contributing for common cause of maintenance of building in a co operative society, co operation disappears & reasons for delay & denial start surfacing.

Human being is susceptible to change & so a structure is. Change in usage pattern different than what it is meant for invite problems. Over loading / size reduction of structural members without proper consultation leads to rupture, in habitability & some times major calamity.

Gardens are made not only at common places or compound but also at box grills & galleries. Continuous pouring of water every day rust grill & its stains along with clay spoil exteriors-plus cause leakages an -floors down-

below. Growth of vegetation is not tackled in time till it create major damage to building.

Abrasion & impact during usage of building add up to issue of durability decrease over & above cyclic & seasonal changes of temperature &. humoidity.

Civil engineering services for supervision is highly disregarded & consultant's role in co operative society sector is presumed to be of measurement taking & checking agency by most members. Also decisions of consulting engineers based on certain technical assumptions & calculations are reversed by client on popular demand of members. Material selection is interfered in favor of companies advertising more & then considered to be more reputed & reliable.

C) Contribution of Manufacturers & Contracting Agencies:

Myth on solid content of polymer played major role in creating many ambiguities & arguments. Active polymer solids, which is right criteria of selection was put to blunt corner. Lack of training / knowledge of representatives added to problem & race of manufacturers did the worst by makins tailor made data sheet": for particular project or making lean product to sustain unhealihy competition. Adulteration in product by contracting agencies reduced expected service life of repairs and clients expecting to get work done at prices below workable market rate became victims of their own greed unknowingly.

Natural/ Geographical Limitations: Soil quality for foundations like, black cotton end up giving long term problems since consolidation / stabilization is costly process. Non availability of proper aggregates in areas like north eastern part of India where transportation of construction materials is a separate project by itself is matter of serious concern to our fraternity to invent alternative source of synthetic nature at reasonable price. Coastal zone buildings are prone to chloride attack & repair requirements are frequent &continuous. Heavy vehicular traffic causes carbon dioxide emission making cover concrete brittle. Natural calamities like earthquake, fire, flood, storm etc. are also the factors to pop up rehabilitation situations. .

Conclusion;

We are all party directly or indirectly, willingly or unwillingly to structural distress situation. Little care & awareness on every ones pan can ensure prolonged defect free life of structure. Jan jagruti abhiyan by every individual civil engineer, construction corporates & government at large could help improving scenario. Training &development programs at every level shall contribute changing today's situation. a

Contd. on pg. 101

accessories, such as spacers, gaskets and setting blocks for compatibility. Incompatible glazing accessories that contact the structural sealant (or weatherseal) can cause the sealant to change colour, and in extreme cases lose adhesion.

The structural joint design should be reviewed by the sealant manufacturer to ensure that the dimensions of the structural silicone (structural bite and glueline) are adequate to support the glass against windload and deadwood, if applicable. The sealants must also be capable of withstanding . calculated thermal movements.

Dow Corning offers a free service to test adhesion and compatibility and review drawings for all structural or weatherseal projects. On completion of testing and print review, a written report is issued detailing surface preparation requirements for glazing substrates, confirming compatibility status for glazing accessories and structural bite and glueline for given conditions.

In conclusion, only structural sealants, which have been specially developed and tested for structural glazing, including Dow Corning® 795 Silicone Building Sealant, Dow Coming® 995 Silicone Structural Adhesive and Dow Coming® 983 Silicone Glazing and Curtainwal! Adhesive/Sealant should be used for structural glazing. These sealants have been proven to perform in extreme climates and earthquakes, and can even be designed for impact and bomb blast resistant glazing.

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Wockhardt Towers, East Wing, Level 2,
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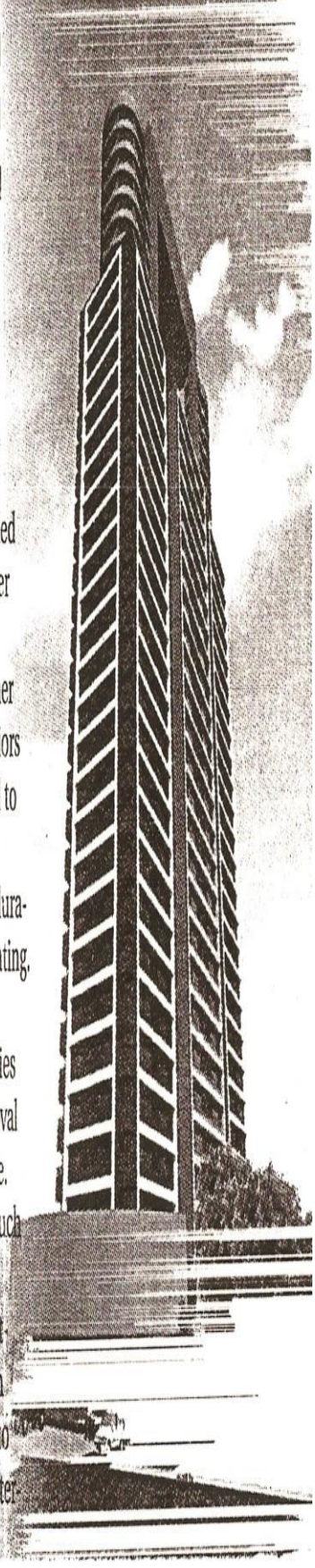
Tel: 022-5694 6868 Fax: 022-5694 6848
Website: www,dowcorning.com ,"||

STRUCTURAL PROTECTION FOR A HOUSE

Protecting the structure of a house is important, the same. SHILPA HASSANI gives a few examples for protecting the foundation of the house



STRUCTURAL protection is considered as an alien word while decorating home is given a lot of importance. While making changes on locations of load bearing walls, changing layouts or covering dry balconies or making French windows, it is very important to seek advice from a structural consultant. Jatin Ambani, owner of Advice Consultant, is a civil engineer with 20 years of experience, in the field of building structural restoration, waterproofing, plumbing, wall seepage control, etc. Jatin too feels that people today are not aware of the ways for protection the foundation of a house or building. Thus, he shares with us some few ideas of how could one provide structural protection to a house.

According to him, no alterations in the original structure of the house should be allowed by society unless expert advice is sought. In interest of one's own house and society at large, owner spending a good amount of money on interiors should also spend some amount for the structural protection of the house. If any exposed reinforcement is found, the same shall be treated for rust passivation using polymers. Plastering such areas directly is like hiding one's own sickness instead of consulting a doctor.

While covering beams or columns with panelling or making fixed furniture, care should be taken to allow access to structural members whenever periodical inspection is required. All leakage lead to R.C.C. deterioration so they must be reported to society immediately and repaired without waiting for fixing financial responsibilities for very long. Every resident of the building should realise that his flooring is some one else's ceiling and he could come across similar problem in future. Structurally weak and old buildings should avoid destructive methods of full plaster or brickbat koba waterproofing by breaking old one, which will damage top floor slab and surrounding structural members. Today's technology provides us solutions like elastomeric coatings on walls to control seepage and APP membrane on terrace after due surface preparation and treating loose substrate removal.

Care must be taken while breaking tiles for replacement by using electrical tools and cantilever areas like balconies should not be loaded heavily since they are not designed for taking load. Grills and weather sheds must be fixed using resin anchors using drill machine rather than using chisel hammer. Interiors professional should get attached to experienced consulting firms in order to ensure protection and durability of property they are decorating. Renovation is need of time and inevitable so municipal authorities also should ease norms of approval instead of making them tiresome. Sanction of a new lift takes as much time as a new building proposal. There could be a separate department with engineers to deal with such municipal approvals so as to avoid unauthorised structural alterations.

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transactions on: REPAIR RESTORATION RENEWAL OF BUILT ENVIRONMENT

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STRUCTURAL REPAIRS AND REHABILITATION OF A COMMERCIAL OFFICE BUILDING AT MASJID BANDAR, MUMBAI, INDIA - A CASE STUDY

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ABSTRACT

A corner located commercial building in South Mumbai in India got damaged for which repair and rehabilitation was needed. The present case study discusses the step by step approaches that was adopted for repair and the effective repair management systematically having numerous constraints of the same building.

Keywords

Micro concrete, Non-destructive testing, Repair, Structural strengthening, Waterproofing

1.0 BACKGROUND

The building structure was G+5 floors and consisted of 249 galas, most of which were being used as small manufacturing units and a few that were being used as offices. The building is 37 years old and has one staircase and one lift. It is located at the corner of two very busy road junction at Masjid Bandar in South Mumbai. A structural audit of the building was carried out to assess its present condition. The building got damaged due to extensive corrosion of its structural members. The existing brick bat koba treatment of the terrace was damaged badly and needed to be replaced with modern waterproofing system. The present case study discusses a step-by-step approach that was adopted for repair and rehabilitation of the building and for effective repair management that systematically had numerous constraints.

2.0 DAMAGE ASSESSMENT

Since the building is located at the junction of two busy roads, this leads to extensive carbonation of thin sections, such as fins and sunshades. The road facing sides of the building (South West direction) had suffered major damage to its RCC vertical fins and sunshades. The damage was so bad that the RCC sunshade collapsed while removing the waterproofing layer on top of it. This building was very close to the sea coast and corrosion took place due to the ingress of chloride ions. There was a double effect of carbonation and chloride ingress that accelerated the corrosion and damaged the structural members of the columns, beams and slabs. The lay out plan for location of column for carrying out NDT is shown in Figure 1.

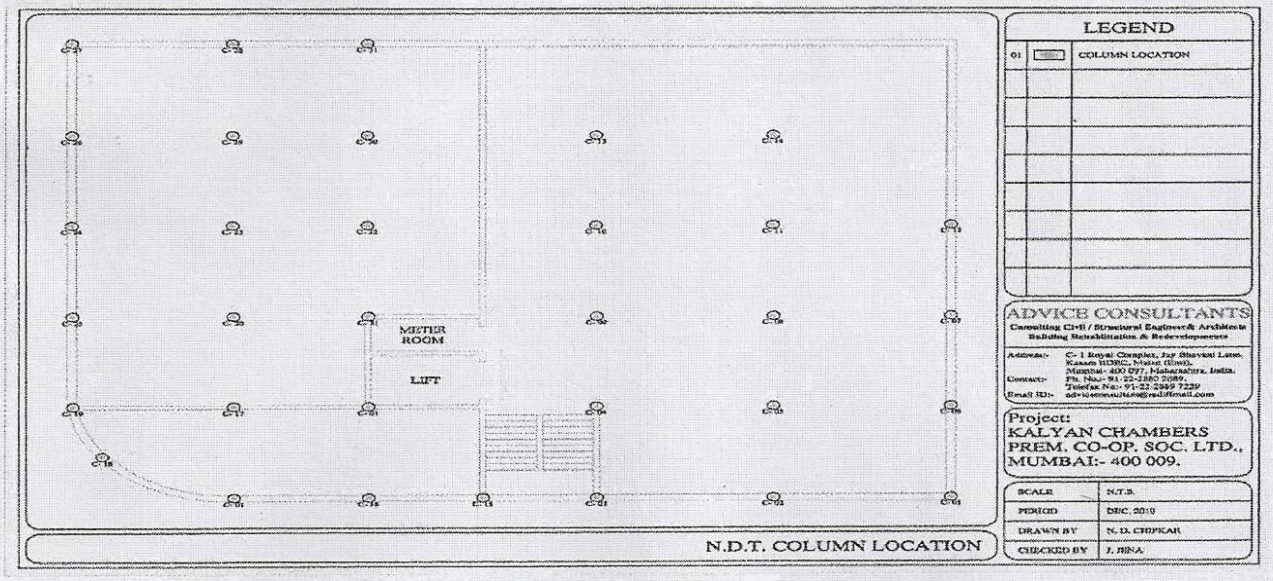

Figure 1. Column location layout plan for carrying out NDT

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2.1 Structural Assessment

Since the building was quite old, a structural audit of the building was carried out as per the statutory norms of the Bombay Municipal Corporation. Visual inspection was carried out and all visible damages, defects, cracks, seepages, dampness etc. were noted, reported and photographed. Further health monitoring of the building was done using non-destructive testing equipment. Rebound hammer (Figure 2) and an ultrasonic pulse velocity (UPV) metre (Figure 3) were calibrated before testing and tests were carried out for accessible structural members like columns and beams.

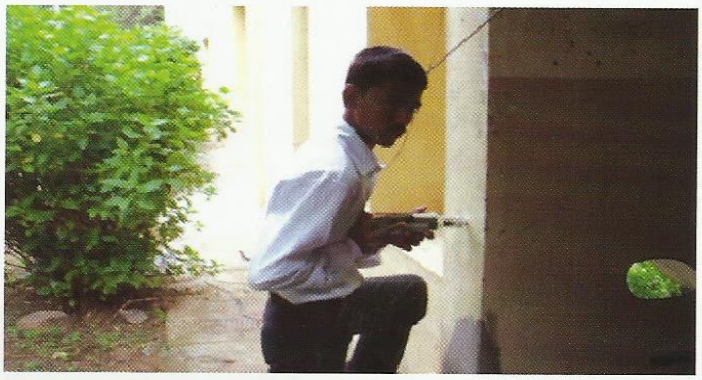

Figure 2. Rebound hummer testing on columns

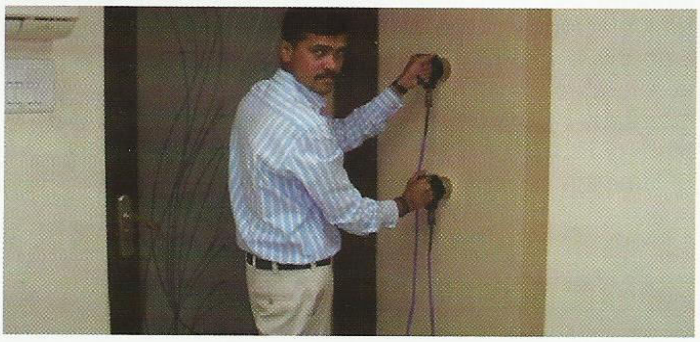

Figure 3. Ultra Sonic Pulse Velocity test for RCC column for soundness

A UPV test is considered to be a valuable and reliable method to examine the interior of the body of concrete in a non-destructive way. It also indicates the quality of the overall length of the concrete through which the pulses are transmitted. The path length (L) of the pulse and the transit time (T) of the pulse are measured using electronic time circuits. The velocity (V) is calculated as, V= L/T. The UPV test in generally used for the measurement of concrete uniformity, determination of cracks and honeycombing and the relative quality between one member and another. The result of UPV test conducted on columns is given in Table 1. Since this was indirect test the correction factor was used to find out the probable UPV results. Out of total 31 columns tested, only two were found having ultrasonic pulse velocity of 4.5 km/s and above indicating excellent quality of concrete, 20 columns were found good quality concrete having UPV results showing between 3.5 - 4.5 km/s and rest nine columns were found UPV results lower than 3.0 km/s indicating doubtful quality of concrete. This classification of quality of concrete is as per IS:13311 Part-1 standard which is given in Table 2. The Rebound Hammer test results were found in conformity with UPV results except few cases where rebound hammer results were showing higher values which may be due to carbonation of the surface concrete.

Table 1. Results of UPV carried on columns

Location	Thickness (mm)	Time (Micro Sec)	Velocity (km/S)
Gr. Floor Col.1	500	115	4.35
Gr. Floor Col.2	500	235	2.13
Gr. Floor Col.3	525	245	2.14
Gr. Floor Col.4	600	145	4.14
Gr. Floor Col.5	600	145	4.14
Gr. Floor Col.6	575	150	3.83
Gr. Floor Col.7	575	145	3.97
Gr. Floor Col.8	500	125	4.00
Gr. Floor Col.9	575	165	3.48
Gr. Floor Col.10	500	135	3.70
Gr. Floor Col.11	475	120	3.96
Gr. Floor Col.12	500	125	4.00
Gr. Floor Col.13	350	85	4.12
Gr. Floor Col.14	375	88	4.26
Gr. Floor Col.15	400	200	2.00
Gr. Floor Col.16	600	255	2.35
4 th. Floor Col.17	450	100	4.50
4 th. Floor Col.18	400	100	4.00
4 th. Floor Col.19	400	95	4.21
4 th. Floor Col.20	400	96	4.17
4 th. Floor Col.21	400	100	4.00
4 th. Floor Col.22	500	125	4.00
4 th. Floor Col.23	400	100	4.00
4 th. Floor Col.24	650	295	2.20
4 th. Floor Col.25	550	250	2.20
4 th. Floor Col.26	500	245	2.04
4 th. Floor Col.27	625	265	2.36
4 th. Floor Col.28	550	120	4.58
4 th. Floor Col.29	425	100	4.25
4 th. Floor Col.30	400	105	3.81
4 th. Floor Col.31	500	225	2.22

Table 2. Quality of Concrete as per IS:13311(Part-1)1992

Velocity	Quality of Concrete
Above 4.5 km/s	Excellent
3.5 to 4.5 km/s	Good
3 to 3.5 km/s	Medium
Less than 3 km/s	Doubtful

Out of those nine columns few badly damaged columns were tested with Half-cell Potential Meter by exposing

reinforcement steel to measure the potential difference between steel and the standard reference electrode of Cu /$CuSO_4$ in contact with the concrete surface (Figure 4).

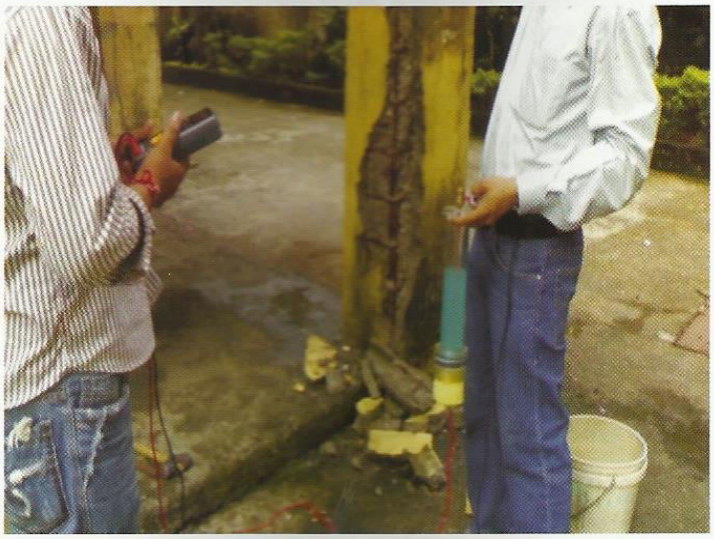

Figure 4. Testing on reinforcement steel to know extent of corrosion and rebar continuity by Half-cell Potential Meter

In all those cases half-cell potential readings were tested between - 400 mV to - 500 mV indicating the high corrosion risk as per ASTM C 876 which gives guidance for corrosion activity in the concrete as given in Table 3.

Table 3. ASTM C 876 guide for evaluation of corrosion activity

Corrosion risk	Half-cell potential (Vs Ag/AgCl)	Half-cell potential (Vs Cu/$CuSO_4$)	Half-cell potential (Vs SCE)
Severe corrosion	Less than - 404 mV	Less than - 500 mV	Less than - 426 mV
High corrosion risk (90% probability)	Between - 404 mV and - 254 mV	Between - 500 mV and - 350 mV	Between - 425 mV and - 275 mV
Medium corrosion risk (50% probability)	Between - 254 mV and - 104 mV	Between - 350 mV and - 200 mV	Between - 275 mV and - 125 mV
Low corrosion risk (10% probability)	Higher than - 104 mV	Higher than - 200 mV	Higher than - 125 mV

Cover meter was used to measure the thickness of the cover concrete. Some core samples were taken from columns for measuring in-situ compressive strength and chemical analysis in the laboratory for measuring the ingress of chloride ions and carbonation. The cores were drilled (Figure 5) and samples were taken to laboratory and suitably capped at both ends and tested in compressive strength testing machine. The suitable correction factor was applied to asses the probable compressive strength. The test results were in conformity with Rebound Hammer and UPV tests. This established the damages in those nine columns due to severe corrosion and followed by development of cracks and delamination which gave lower UPV test results. Accordingly decision was taken to repair and strengthen those columns. A moisture meter survey (Figure 6) was carried out to locate the area of dampness and seepages for further waterproofing work. The basement was closed while the survey was conducted, and some parts of the structural members inside offices were covered by tiles or wall panels or false ceilings. The structures suffered more damage in areas that were not surveyed, which accounted for the major part of the estimated cost. This resulted in an overall increase in the budgeted amount. The amount allocated for structural glazing and aluminium composite panel work was re-allocated to the work on these hidden areas of restoration, as it was felt that health issues should be addressed before beautifying the building.

Figure 5. Core cutting of concrete to test chemical properties and compressive strength at lab

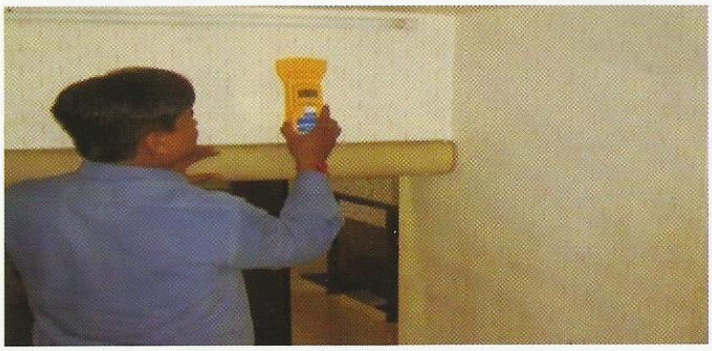

Figure 6. Moisture testing on wall for leakage detection

3.0 REPAIR AND RESTORATION

The basic scope of the project assigned was for general repair, structural repair, terrace waterproofing, part replacement of sanitary and plumbing, external waterproofing, re-plastering, painting of common areas and external painting.

3.1 Erection of Scaffolding

Due to space constraints, scaffolding was erected over the footpath on two sides of the building and in the society compound on the third side. The third face has a little bit of ground space where the water tank, shuttering materials, debris, cement, construction chemicals and sand were stored.

3.2 Breaking of Plaster and RCC Sections

It was suggested that the vertical fins (Figure 7), which were just for the purpose of elevation, should be removed completely to reduce the dead load and future maintenance cost. It took considerable time to break the RCC along with its reinforcement and to level the broken area as per the elevation design (Figure 8).

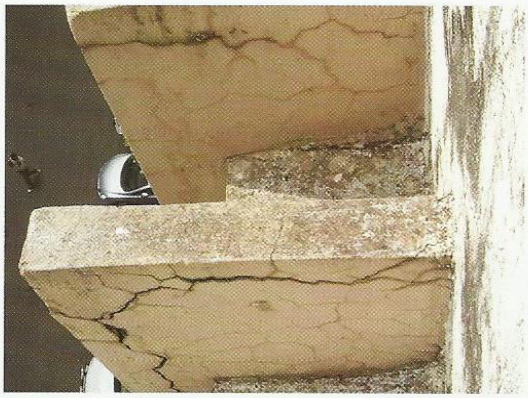

Figure 7. Elevation pardi before pardies

Figure 8. View after breaking non structural elevation

3.3 Re-casting of RCC Sunshade

It was suggested that a continuous sunshade Figure 9 be constructed for protection against rainwater, instead of the old sunshades just over the window openings. This helps prevent water running over empty spaces along the walls that results in the growing of moss and fungus, which causes the appearance of black spots and spoils the paint. All new re-bars were anchored to the beam with the help of FISCHER epoxy resin capsules and 100 mm thick reinforced concrete was cast uniformly with the help of waterproof ply shuttering.

Figure 9. Continuous sunshade being provided

3.4 Plastering

Old and new plaster was joined using a bonding adhesive for proper bonding. PP (Polypropylene) Fibres were used as transverse reinforcement to join the first and second coats of plaster consecutively, in 1 : 4 and 1 : 3 cement mortar ratio. Liquid waterproofing compound was added as an admixture in the mortar. The gaps between the RCC and masonry were filled by a polymer modified mortar, embedded with metal aggregates. The properties of polymer modified mortar and the standard specification is given in Table 4. Fresh pointing was done in loose brickwork wherever bedding and jointing mortar had disintegrated. Dash coat plaster was provided wherever loss of brick/block work required the application of a mortar thickness of more than 25 mm.

3.5 RCC Coping

To prevent leakage on top of the parapet, RCC coping was laid over at a height of a 1.04 m parapet wall with 25 mm projecting outside, 75 mm projecting inside and

Table 4. Properties and standard specification of Polymer Modified Motor

Properties	Specification	Results
Appearance, Powder Liquid		Free flowing powder Milky white emulsion
Mixed density, kg/m^3		2100
Pot Life @ 25^{0}C, minutes		30
Setting time, in minutes - Initial Final		210, 270
Compressive strength-28 days, N/mm^2	BS : 6319 : part 2	45
Flexural strength, 7 days, N/mm^2	BS : 6319 : part 3	7
Tensile strength, 7days, N/mm^2	BS : 6319 : part 7	2
Water absorption, %		< 0.5
Bond strength, N/mm^2	BS : 1881 : Part 207	1.5
Depth of carbonation in mm		Nil - Passes the Accelerated carbonation test, after 2 & 4 hours
Chloride content		Nil

a top finish of a 25 mm inward slope. Making shuttering on three sides has no complication because of the scaffolding support. The fourth side was also cast with additional safety measures. RCC coping before and after are shown in Figure 10 and Figure 11 respectively.

Figure 10. RCC coping before

Figure 11. RCC coping after

4.0 STRUCTURAL STRENGTHENING

The external columns, beams and slabs on the ground floor and the columns and beams on the top most floors deteriorated very badly and were repaired with a polymer modified mortar and micro concrete. Fibre wrapping on a few columns was done to enhance the strength of these weak columns. The properties of micro concrete and the specification standard are given in Table 5.

Table 5. Properties and standard specification of Micro Concrete

Properties	Specification	Results
Compressive strength	ASTM C 109 : 99	20 N/mm² at 10 day 40 N/mm² at 30 days 62 N/mm² at 40 days 70 N/mm² at 50 days
Flexural Strength	ASTM C 580	11 N/mm² at 5 days
Tensile Strength	ASTM C 307	6 N/mm² at 7 days
Pull Off (Bond) strength	BS 1881, Part 207	1.6 - 1.8 N/mm²
Carbonation resistant		Passes the Accelerated carbonation test
Water absorption after 24 hrs (%)		0.45
Chloride content		Nil

All the old bars were cleaned with rust remover. 24 hours after application, the surface was cleaned with water jets so that all rust and loose concrete was cleaned thoroughly. Wherever reinforcement bars lost more than 25% of their original diameter volume, additional rebars were provided as replacement/ replenishment. Old and new bars were coated with a rust preventer, as a passivator coat. One or more coats were applied using a ready-to-use powder that was mixed with water and modified with powder polymers. The new reinforcement was connected to the original concrete by fixing Shear Connectors, using polyester resin anchor fix grouts. These connectors were fixed using a chemical based grout that has high pullout bond strength by drilling a hole into the concrete of a minimum of 100 - 150 mm in length. It was ensured that the pullout strength of that anchor was more than the tensile strength of the bar. After 24 hours, the entire surface was coated with a long pot life epoxy bond followed by a watertight shuttering, prepared to pour micro concrete.

The beams and slabs in the basement were damaged Figure 12 due to leakage from the common WC block on the ground floor. A complete beam was jacketed in micro concrete by drilling a hole from the top floor. A portion of the slab bottom sagged and de-bonded. By providing watertight shuttering, slab casting was done using micro concrete with 6 mm down pea gravels poured from the top floor by making a few core cuttings for maximum flow up to 2 metres Figure 13. Similarly the damaged columns were strengthened were micro concreting. Figure 14 and Figure 15 show the column before micro concreting and column after micro concreting respectively.

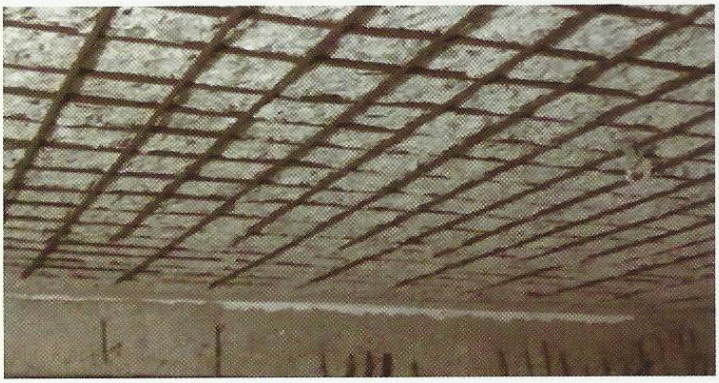

Figure 12. Roof slab before micro concreting

Figure 13. Roof slab after micro concreting

Figure 14. Column before micro concreting

Figure 15. Column after micro concreting

5.0 EXTERNAL PROTECTION TREATMENT

The external surface of the building was protected again with good quality coating that had elastomeric properties. A hand roller was used for application instead of a brush. Three coats were applied with the hand roller as per manufacturer recommendations. Acrylic coating was used having crack bridging properties. This is very important for old buildings. A five year warranty against leakage was received and given to the client stating that the manufacturer will give free material during the tenure of the contract and the contractor will apply the material at no extra cost to the Society during the defect liability period. Such work will start within a week after a written intimation of complaint is submitted. The work will be done under supervision of the consultant till the defects are rectified. Figure 16 and Figure 17 show the external treatment with primer and finished coat respectively.

Figure 16. View after primer coat

Figure 17. View after coating

6.0 WATERPROOFING

6.1 Waterproofing of Sunken Slab of Toilet

There was a large sunken portion in the ground floor toilet that had an Indian W.C. This did not allow usage of the area below it. The toilet was also leaking, which caused major damage to the basement structural members. This was waterproofed using the traditional brick bat koba method and the W.C. was changed to a European W.C., thus avoiding the sunken area. A flat slab was cast and this released a large area at the basement for actual use. The concealed plumbing was changed and the tiles were replaced with bigger tiles, as per the owner's suggestion, to reduce the number of joints. Many other toilets on the upper floors were also waterproofed in a similar manner, as per their availability.

6.2 Waterproofing of Enclosed Balcony Roof at Top Floor

The top floor balcony was enclosed and was used as an office. This had wooden frames with AC (Asbestos cement)sheet roofing. It was leaking at all junctions between the walls and the roof. The wooden truss had deteriorated and the AC sheets had cracked. The AC sheets and wooden supports were replaced using new sheets and steel structure supports, without damaging the false ceiling. A part of the false ceiling was damaged while replacing the roof, but the false ceiling was also repaired on the same day as monsoon showers were imminent.

6.3 Waterproofing of Terrace Floor using Torch Applied APP Membrane

Looking at the condition of the top floor slab (Figure 18), it was impossible to remove the existing brick bat koba waterproofing. Also the imminent monsoon made it impossible to put new brick bat koba impossible, as the process is time consuming and the stacking of so much debris would not be easy. A decision was taken in favour of the non-destructive fast application method of bituminous hot application PP reinforced membrane. The APP (Atactic Polypropylene) membrane was fixed in a day, after application of bituminous primer on the entire roof on the previous night, and it was extended up to drip mould of parapet plaster. A rainwater outlet of an adequate size was made available to avoid water stagnation and the APP was extended to the inside of the rainwater pipe opening. APP laps were maintained uniformly and torched at softening point (Figure 19) to melt properly to avoid hiccups and make joints watertight. The parapet top was finished with sand face finish plaster and the top was covered with APP membrane for additional protection (Figure 20). The properties of APP membrane and the specification standard are given in Table 6.

Figure 18. Before roof waterproofing

Figure 19. Torch on application of APP membrane for terrace waterproofing

Figure 20. After completion of laying APP membrane on terrace

Table 6. Properties and standard specification of APP Membrane

Properties	Specification	Result
Roll size, 10 m X 1 m	ASTM D 5147	10 X 1
Thickness of membrane, mm		3
Roll weight, kg		32
Carrier type & weight, gm/m^2		Polyester 160
Coating asphalt		APP modified
Softening point, ^{o}C		150
Penetration at 25^{o}C, d (mm)		15 - 25
Tensile strength, L/T, N/5 cm	ASTM D 5147	700 / 550
Elongation at break, L/T, (%)	ASTM D 5147	40/50
Tear resistance, L/T, (N)	ASTM D 5147	140/160
Resistance to water pressure		No leakages
Water absorption, (%)	ASTM D 471	Max 3.2
Heat resistance	ASTM D 5147	No flow at 125^{o}C
Cold Flexibility	ASTM D 5147	No cracking

7.0 PLUMBING AND DRAINAGE WORK

7.1 Water Supply Plumbing

Composite plumbing in all our previous projects have proved to be a boon against corrosion problems faced using metal pipes and UV instability of many plastic pipes. Large length availability, without joints for upto 200 m was an additional attraction, particularly for loop line. Malleability of composite pipes upto 63 mm diametre has proved useful in maintaining curves of parapet walls of building peripheries without elbows/ couplers. All plumbing lines had GI pipes (Figure 21) partially embedded in to walls and in many rusty/leaking joints. These pipes were replaced with new composite KITEC PE-AL-PE pipes (Figure 22) and fittings. Special

clamps were used to fix the pipes at 1.5 m intervals and fixed with FISCHER anchor fasteners. The client got a 50 year manufacturer warranty for pipes. Composite fittings were used in external lines and brass fittings in concealed lines for bathroom leakage. Windows were provided with Cudappa stone framing to access pipes through parapet walls to connect loop lines with down take pipe lines.

Figure 21. GI pipes used before

Figure 22. Pipes after replacement with KITEC PE-AL-PE

7.2 PVC Drainage Pipes

Drainage pipes were leaking at many connector locations and were not fixed properly. These PVC pipes were removed and realigned over the special clamps, at all locations. Wherever the pipes passed through the RCC weather sheds, a bigger size pipe sleeve was fixed in the RCC for easy maintenance to ensure that there is no breaking involved in the future for pipe movement. UV resistant black KITEC pipes, with a carbon black ingredient, were used with fittings. All toilets were kept operational by providing temporary PVC pipe lines during repairs, one metre away from the wall, and were fixed permanently once connector waterproofing was done and civil work behind pipe areas was completed.

7.3 Under Ground Drainage

It was found that the basement was leaking on account of the failure of joints of old stoneware pipes and bedding pointing mortar of man hole brick work over and above the joints of pipes to man holes. The entire system was renewed and realigned using UPVC SWR pipes with new manholes. Even old cast iron gully traps were replaced using UPVC ones. The new system was connected on Sunday, as it was a holiday and the offices were closed. Old pipes and manholes, which were not removed, were abolished. Paver blocks were suggested for the compound after such repairs. Concrete plinth protection work was done to ensure that no water seeps through the ground to the basement.

8.0 OBSTACLES IN THE PROJECT

Since the building was located in a highly crowded area and the two front faces of the ground floors were occupied and operational because of commercial shops where the people were regularly moving in and out, it was quite difficult to handle the project. However, a systematical repair management approach could overcome many obstacles. The obstacles, and tackling them effectively, are discussed as follows:

8.1 Storage of Materials like Cement and Sand

There was not much space to keep construction material. Whenever material came in trucks it was unloaded on the footpath/road at night because the local authority would not allow any material on the road. The contractor had to remove the material before the next morning. This required extra manpower during the night almost every day. Also, it called for acute material management to ensure that there wasn't any extra material ordered or sent to the site and there was no delay in ordering/ procuring material where work would suffer due to lack of material availability. Thus, it was a classic example of serious logistics handling and supply chain management.

8.2 Safety Measures and Debris Removal

A working platform was constructed using structural steel beams, ply wood, old bamboos and G.I. sheets to prevent debris falling from a height on commuters/ visitors of the shops or even people working down below. Safety belts, helmets and other safety norms were strictly used by all workmen. While breaking, the debris over the platform had to be cleared at regular intervals to ensure that overload on the platform is not a safety hazard. As there was absolutely no space to store debris on the ground floor, there was no option left but to remove the debris at night or off office hours by paying heavily to get it done and making the debris stand till loading was done directly from the platform to the trucks. The debris removal trucks were sometimes called for half load at times.

8.3 Municipal Permissions

Necessary permission was obtained from the various departments like Road and Footpath, Buildings, Mosquito and Water Departments. There were many incidents when the Municipal footpath clearing team would take away the chemical cane, cement bags and mixing trays while work was underway and while mixing and lifting of repair material was being done on the footpath on two sides of the building.

8.4 Time Frame

The tender period to complete the project was 6 months but the quantum of work increased to almost double. It was impossible to complete the work in the decided time and value. The project was completed in 9 months time as there were also issues of getting permissions from members by calling special general body meetings for additional contributions and mode of collection. The society also took permission from the Registrar of Societies to withdraw amounts up to 85% from the sinking fund for the project, repayable in instalments in next 3 years. This reduced the burden on members to shell out major amounts at a time and gave them the facility to pay the society back in instalments to replenish the sinking fund meant for use in such emergencies. The consultant's report helped in finishing this formality in time with all appropriateness and fairness.

Figure 23. Elevation of the building before repair and rehabilitation

9.0 CONCLUSION

These types of structures need to be surveyed very carefully, if required sample portion may be opened to identify the condition of the core and level of corrosion. A survey must be conducted in all areas, especially enclosed / closed areas, by getting access when available. Extra time should be considered for difficult situations like working on platforms or over the footpath/public commuting areas. Execution can be performed well if owners clear the areas surrounding the structure in time and mutual cooperation is achieved between members to achieve long-term durability goals. However, with all those constraints, the repair and rehabilitation work of this project was completed satisfactorily. Figure 23 and Figure 24 show the elevation of the building before and after repair and restoration respectively.

Figure 24. Elevation of the same building after repair and rehabilitation

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