Chapter 5

Conceptual Construct: Formulation Strategy
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Conceptual construct for emerging large-span mega-space forms have been formulated in the context of foregoing groundwork studies conducted. And the following forms have been developed with such a key idea in mind— as an extended-study-patterns, presently.

A rational vision for quality control in construction systems has been also suggested for developing new technological large-span mega-space forms, vis-à-vis present status. The following formulations have been presented here with such a reflection of mind. The contents of this chapter are as follows:

5.1 Suggested Patterns of Development.

5.2 Quality Control in Building Projects: Concept and Practice.
5.1 Extended-Study-Patterns: Suggested Patterns of Development

The study regarding patterns of development for maximum contribution effects was carried out, independently, on four basic modules (units) in step-size of 1/12 (in each attempt) for Diamond-shaped GN (Grid-Nodal) Stiffeners (base formation) as:-

1. 17'3" (5.25 M) 5. 86'3" (26.25 M)
2. 34'6" (10.50 M) 6. 103'6" (31.50 M)
3. 51'9" (15.75 M) Optional (Stiffener length is likely to become 30'0" and 36'0" in length). Hence discouraged for adopting these modules.
4. 69'0" (21.00 M)

From the sampled-study of these modules in Section 3.5, it was inferred that :-

The system represented significant contribution at (dot) (a/A = 2/4; b/B = 1/4) or within 10% range, on either side of Junction Point. This was the most effective pattern of development for significant results (in-over-all effects contribution) mentioned there.

These modules will now be used to develop other larger (Mega) dimensional transformations, as an extended study-patterns in this Chapter— as suggested large-sized formulations strategy.

(1) 17'3" X 103'6" (1x6)
(2) 34'6" X 103'6" (1x3)
(3) 51'9" X 103'6" (1x2)
(4) And many more likely combinations.
Figure 5.1: Patterns of Development Study for Module 1: 5.25 metres X 5.25 metres

Figure 5.2: Patterns of Development Study for Module 2: 10.5 metres X 10.5 metres
Figure 5.3: Patterns of development study for Module 3: 15.75 metres X 15.75 metres

Figure 5.4: Patterns of development study for Module 4: 21.00 metres X 21.00 metres
Development of Structural-Modular-Spaces for Creating Flexible Space for Wide Ranging Requirements

Following Select Patterns have been Developed as under:

Figure 5.5: Structural-Modular-Space Pattern 01 (5.25 meters X 21.00 meters)

Figure 5.6: Structural-Modular-Space Pattern 02 (10.50 meters X 21.00 meters)
Figure 5.7: Structural-Modular-Space Pattern 03 (5.25 meters X 31.50 meters)

Figure 5.8: Structural-Modular-Space Pattern 04 (10.50 meters X 31.50 meters)
Figure S.10: Structural-Modular-Space Pattern 06 (31.50 meters X 31.50 meters)

Figure 5.9: Structural-Modular-Space Pattern 05 (15.75 meters X 31.50 meters)

Figure 5.10: Structural-Modular-Space Pattern 06 (31.50 meters X 31.50 meters)
Figure 5.11: Structural-Modular-Space Pattern 07(63.00 meters X 63.00 meters)
5.2 Quality Control in Building Projects: Concept and Practice

Structures that are built have to perform. This basic truth is not disputable. Rapid advances in technology have yielded better, economical and more sound structures. Paradoxically, however, the rate of failures and that of ‘performance deficiency’, have increased.

The construction process is an extension of the design process, and deficiency either in design or workmanship is neither forgotten nor forgiven. Depending upon the quality of inputs in the form of architectural design, structural design, provisions of detailing, specifications and construction workmanship, will bring out the optimum performance of the structure. Therefore need for focussing attention on ‘deficiencies’ at all levels from design to construction to completion, is of crucial importance.

Another important aspect of the issue is that the common lay people have faith in the professionals. They justifiably hold the view that the structures these professionals design and build will perform satisfactorily. If, however, they fail to do so or they collapse, society’s basic faith in the architects, engineers and builders i.e. (contractor) gets shaken. It tarnishes the public image of the professionals. Additionally, the severe effect as a consequence of poor structure performance and / or collapse, shatters the morale of the architects-engineers-builders team associated with such mal-functioning built structures.

The direct and indirect causes of collapses and/or deficiency in performance of built structures are mainly four, singly or in combination, namely:-

* Design errors.
* Construction errors.
* Material deficiencies.
* Sub-standard workmanship. (workmanship being a critical component).

It is therefore necessary to systematically induct into the whole process in-built mechanism to minimise these shortcomings by effectively monitoring a proper quality control mechanism into the project from start to finish.

A building is conceived, then designed, is born when built, becomes alive while standing, and dies at an old age or after an unexpected accident. The linkages of the construction project from conception of a structure till its completion must be properly understood by the designer team i.e. by the Architect, Engineer and Consultant (if any) etc.
5.2.1 Review of inputs

(1) The building plans are prepared to suit planning regulations based on plot size so as to utilise full permissible construction area.

(2) Planning provisions supported by the impressive elevations treatment is accepted by the clients. Clients then leave major issues to the architects, engineers, and the contractors.

(3) Most of the routine type of constructions are carried out without adequate support of working drawings, and also without essential construction details.

(4) Structural drawings are seldom more than framing plans and schedules. Essential details of structural joints, projecting members, reinforcement congestions, lap locations, reinforcement layouts, and stress concentration areas etc., and many such details – are never covered in detailing.

(5) Site supervision also never points out these grey areas, and never demands this missing information.

(6) Important service drawings, namely, sanitary, plumbing, are seldom available on site. They are in fact never prepared. If at all prepared, they are schematic only for the approval of statutory bodies.

(7) Details for efficient water-proofing, leak-proof laying, joint-sealing, is never provided and ensured. The outcome is obvious. The structure is affected with usual damage particularly in the form of spread seepage within.

(8) Plumbing work seldom gets the benefit of the architect’s professional touch. Entire plumbing layout is required to be pre-determined and superimposed on plan finalisation as this permits to avoid damage to masonry and/or concrete later on, and also checks on the effectiveness of the plumbing for corrective measures, if required. At a later stage, there is hardly any supervision possible on plumber’s work and damage observation cannot be properly mended.

(9) Electrical wiring must have the required load carrying capacity— as continued electrical mal-functioning is a safety hazards.

(10) Mortar, the most important factor in bonding is totally neglected. Its quality is never controlled. Use of ‘set’ mortar is routine. Waste of cement slurry from mortar is permitted without any concern.

(11) Hacking of column surfaces and beam bottoms which are in contact with masonry work is never done for adequate bond, inviting separation cracks.

The above occurrences are due to inadequate construction information made available at site and no reciprocal demand from the site staff to the professional design office.
5.2.2 Design Office Deficiencies

Quality is never an accident. It is always the result of high intention, calculated efforts, intelligent direction and skilful execution. It represents the wise choice of experienced professional expertise.

There also prevails an erroneous impression that quality control of a building project begins only at the construction site. This is not correct. Quality control has to begin at the professional design office, as there are numerous deficiencies existing in the design office itself.

Most of the problems, whether architectural or structural, originate in the design office where the project is conceived. What constitutes the structure is decided here. This is depicted in the form of drawings, calculations, details, all worked out to the extent felt necessary. The need to define how much is necessary and its quality governs the performance. Quality of the presentation, specifications and workmanship, decide the shape of things to come. Its completeness, with sound approach, safeguards the stability of the structure, and its performance.

Designers have, therefore, to be alert to avoid anything wrong entering the projects in their professional office.

Some of the major deficiencies in the design office are summarised below. The list is not exhaustive, but— only indicative:-

(1) Negligent survey of land contours, drainage, existing site conditions, omission to check further if site is reclaimed land, filling depths, soil properties, water-table levels (during dry and wet seasons), soil bearing pressures, etc. to correctly design foundations.

(2) Incorrect assumption of loads, analysis and flexural behaviour.

(3) Errors, omissions and mistakes in design calculations.

(4) Errors in design assumptions or defective structural systems.

(5) Poor detailing and drafting.

(6) Careless treatment and development of structural connections between members.

(7) Improper locations, spacing, provisions of reinforcement and splices.

(8) Inadequate concrete-cover to the reinforcing steel, resulting in early corrosion, carbonation, damage to concrete, spelling etc.

(9) Overlooking or inadequately providing for severe secondary stresses and their effect, particularly creep, thermal movements and shrinkage etc.

(10) Deficient shear and torsion shear provision.

(11) Omission to provide expansion joints and their details.
(12) Omission to provide leakage and seepage details at appropriate locations.

(13) Negligently providing overlapping reinforcement bars in locations of high stress intensity.

(14) Not avoiding of bunching of bars in large-span framed structures.

(15) Drawings not checked before they leave the design office for execution. Each one peruses the drawings, but no one really knows what to check. Therefore mistakes continue.

(16) If a design proposed is of a very special type, and demands higher level of skills for successful execution, even with proper drawings the designer should give at side note for providing expert site supervision, and should be guided at site by more experienced persons.

In the design office, to avoid overlooking a mistake, a deliberate involved process is necessary. A format to check drawings and calculations with "checked by" stamps may not serve the purpose. It is easy to sign and avoid any further dialogue. This is dangerous.

The head of the design team should be made responsible for all the checking procedures, after checking by the central quality control department. It is not advisable to delegate this important work to a junior level checker.

Professional offices should be made aware about the need for efficient and effective controls at design stage and quality control aspects thereof. Overload is a common phenomenon in a design office and leads to increasing the probability of errors in the design. For special structures, checks and cross-checks are an extra must, and are very risky to avoid. Overlooking this extra care can result in serious consequences.

5.2.3 The Construction Process

As has been stated at the very beginning, the construction process is an extension of the designs process. For a safe structure to emerge, this front needs to be carefully monitored by the designer professional. It must be understood that, whereas good workmanship and quality materials can make up some deficiencies of design, good design cannot rectify the deficiencies of poor materials and poor workmanship.

Whereas quality control is the most important discipline in construction for the Indian scenario as prevails at present, basic awareness about good construction practices is lacking. This applies to almost everything on the construction front, i.e. in brickwork, concrete, timber, joinery, centring, scaffolding, reinforcement work, plumbing, electrification, etc. This scenario needs a radical
change in our professional approach to improve inputs for serviceable and durable structures.

It is a common observation that most of the construction materials and their on-site utilisation are not of required quality. There is a tendency to compromise on even the important issues. It is absolutely necessary to construct a right thing in the first instance since it cannot be set right afterwards. The outcome of these lacunae leads to structures with avoidable functional problems.

On the construction front another important point to take note of is that collapse occurs more frequently during construction than during the useful life of the structure. Statistical surveys of construction sites gives the relative ratio of such happenings as 30:1.

It needs also to emphatically brought out that in the prevailing Indian scenario construction supervision is grossly inadequate, and this important shortcoming is devoid of awareness. This is due to lack of specific education training and orientation for quality management in the mechanics of the construction industry and this lacuna needs to be removed, if quality arrangement in the mechanics of the construction industry is to be improved.

We are all aware that a doctor has to undergo internship and residency as a part of medical training (as a prerequisite to his academic qualification) before he starts practising medicine, and treating the sick. No such quality control experience is provided in the training of those in the building profession i.e. to architects, civil/structural engineer and even to the artisans. This missing dimension needs to be removed.

In the present type of set-ups on the construction sites, construction quality is not likely to improve in the near future. And it may take quite some time to achieve the needed quality improvement if adequate background support of trained and skilled artisans, trained quality supervisors, and quality awareness at all levels is not brought about, and construction work projects continue to be let-out to lay/non technical contractors, not qualified to deliver quality work on the construction site.

5.2.4 The Lowest Tender Syndrome—its Effect on Construction Quality

The lowest tender concept of letting out construction works is at present in vague in India. This has been considered as a good tool for economy control of financial management. Paradoxically, this works as a deadly enemy for quality control in construction. Competitive bids cut to the bone and beyond ruthless control of expenditure on the project site at the cost of quality. Obsessed with competition we compromise for the lowest cost— which means lowest quality, because work
done in whatever manner, poor or sub-standard, begins to be accepted. The workers, the foreman and even the Engineer Supervisor cannot ensure required quality control.

The aphorism relevant to the issue here is: "it is unwise to pay too much, but foolish to pay too little. When you pay too much, you lose a little money" — that is all; but in the construction industry when you pay too little, you sometimes lose much or everything, because the thing you have constructed is incapable of performing what it was expected to do. It is indeed an irony of fate that by accepting the lowest bidding constructors, we are forced to bring the cheapest materials, sub-standard workmanship, and yet expected to give best performance!

As a corollary to the theorem expounded in the para above, it can be stated further that securing contracts, well below affordable professional costs, leads to numerous construction hassles, deficiencies, delays, and all-round sub-standard work. There is enough debate on awarding construction contracts to the lowest bidder and the problematic outcome is common in every project, namely, sub-standard work quality, hassles causing delay in execution, intricate arbitrations, cost escalations and extensive costly litigations. This peculiar water-tight culture of the lowest bid is thus a serious hurdle to quality control on the construction site. If the quality control site engineer acts with firmness to secure quality control— work is stopped/delayed on the work site, and allegations of motivated harassment are slapped upon him. If he becomes lax and compromises to accept sub-standard works, work quality on all fronts of the construction project is jeopardised.

5.2.5 Importance of Access during Construction for Quality Construction

The access in construction is a means towards any given location of work at a given height either internally or externally. Unless proper access is provided, quality construction cannot be achieved.

Internal access is conveniently available due to flow to floor construction. External access, however, is rarely provided during constructions except for external finishing works. Thus external work quality is left to guess-work. The present day constructions almost throughout India do not provide required external access during construction. The external areas of work consist of structural concrete framework, masonry cladding, external plaster, plumbing works, external decorative finishes, painting, protective coatings, and many more. Apart from suspect material and workmanship quality mis-alignments of line levels, lack of adequate work safety to the artisans and limitations of safety of bamboo scaffolding to quality control supervising staff, does not pursue the achievement of construction quality requirement.
Whereas several improvements in modern scaffold requirements are now available, they are generally high investment proposals and also pose subsequent stacking/storage problems during idle periods. Additionally, this type of scaffolding is not easily available on rental basis. Their use is, therefore, avoided and resort is made to one lagged bamboo scaffolds with ongoing punctures in walls just adequate to meet constructive demands. Gondola suspenders for use on external faces have not yet come into vogue in this county yet. These are, therefore, only a rare sight on construction site.

Seen from the above background and providing proper work access should, therefore, be made compulsory, and payment provision should be made in the contract with such provision both work quality and work progress can be definitely improved. Access and safe scaffolds are therefore a must for quality construction.

5.2.6 Quality Construction needs Construction Safety

Safety and quality could go together, but quality without safety is not possible. Civil construction is carried out by participation of the human element. Without safety provisions no one would venture to go out of the way to risk one's life. Inadequate safety, risk involvement thus are certain to affect work quality. There are vast areas of construction work with inadequate access and safety for workers requiring acrobatics for work execution and work inspection and, therefore, work suffers in quality. As such it is necessary that safety culture is insisted upon as a discipline throughout the construction industry. It should be accepted as a must provision on the construction site. It also saves site personnel from serious accidents and heavy financial compensations to the accident victims.

5.2.7 Lack of Designer's Involvement in Construction

It need hardly be stressed, that detailed day-to-day supervision does not form part of the designer's obligation. First, he cannot afford this in his fees. Even if he is paid extra, he cannot afford the time to supervise, as being a good, highly experienced, sincere and conscientious designer, he has to attend to several other commitments simultaneously. The personal attention to the extent required, at the time required, and at the location required, is thus not available. The only alternative option left to him is to delegate his authority by appointing technically trained quality control supervisors (normally difficult to secure) on the project site, paid by the clients. Obviously, the quality of supervision by someone else cannot be compared with the designer's own persona. Therefore, assured quality controls become difficult. At any rate, the prevailing practice as exists in India today, this is
the pattern of construction site quality control that is available to make the best of, usefulness.

5.2.8 Expansion Joints need Special Attention

Joints are placed in the structure to limit the magnitude of the forces which result due to volume change deformations, temperature changes, shrinkage, creep, and to permit movements of structural elements. Width of the joints are calculated theoretically using coefficient of expansion of unit length for normal concrete construction. Maximum width recommended is 25mm, however width of 40 mm is common.

Expansion joints are interruptions in the construction sequence. Provision of appropriately detailed expansion joints are of utmost importance for their effectiveness. Omission of important details result in mal-functioning, and become an eyesore in the building due to continuous seepage, leakage and severe discoloration including structural damage. Ongoing dampness leads to corrosion damage.

The expansion joints traverse along the external face of the building right from the plinth upto the terrace. Whereas detailing of the expansion joint is done in the design office, sufficient care has to be given to it during construction and terrace waterproofing.

It is important to note that expansion joints, if provided, must be with adequate detailing from the design office. If such detailing is not provided, or is only skeletal, these detail drawings must be specifically asked for by the quality control supervisor on the work site. It must not be left to the whims and vagaries of the contractors. Location of the expansion-joints should also be based on the decision of the design office, and ,if not given, should be asked for. It should not be arbitrarily fixed at 45m distance rigidly fixed by the codal rules, which rules should be taken as broad guidelines only. Further, care should be taken at the construction site to ensure that expansion joints are not disturbed inadvertently by construction over the joints. Also, the frame movement creates 'push and pull' in the filled materials, and there specifications must be clearly lay down and checked at site before use. Strict quality control is of utmost importance at the time of the expansion- joints and must not be shown laxity or ignored, or left only to codal provisions, which are only broad guidelines.

5.2.9 Quality Control, with Focus on Construction Sites

Quality control is the most important discipline in construction. To implement the same, the site organization must develop proper checking and re-
checking procedures with the overall knowledge and consent of the professional design office. Actions needed to effectively control work sites are being summarized here under. These are only indicative, and may not be taken as exhaustive: -

(1) Competent and strict supervision is an absolute necessity. Plan it and ensure it.

(2) Quality control works only when all levels of management insist upon it, are committed for quality and every employee and worker at site knows it. Therefore, create and ensure the needed co-ordination.

(3) Strict quality control must start right from the beginning, so that the builder/contractor would know the level and quality of work expected of him. It is difficult to tighten the contractor all of a sudden at mid-stream.

(4) It must be kept in mind that there is hardly any control culture worth the name existing in the Indian sub-continent in comparison with what is practised in Western countries—except for testing concrete cubes/cylinders. With such a background the task of creating quality control culture becomes formidable. With dynamic input create the environment by appointing quality control supervisors, monitor actively and enforce action at appropriate levels.

(5) Doctors cannot work without nurses; likewise building contractors cannot perform qualitatively without construction foremen. Insist on the contractors to employ them and see that they are found and employed.

(6) Take action to ensure that all architectural and structural design drawings and detail sheets thereof are secured from the design office and are available for ready reference. Any drawings and/or detail sheets needed, but not received should be asked for promptly and pursued vigorously, till received for use at site.

(7) General specifications and special specifications governing the work and a certified copy of the contract agreement relating to the work should also be secured for ready reference on the work site.

(8) Materials brought to site for use in construction should be test-checked carefully for assured quality. Sub-standard materials received should be summarily rejected and got removed from site to ensure that these are not used on the sly.

(9) Safe access to all points of construction work at site is a must and is most important both for workers and for supervision. This is seldom adequately provided. No laxity should be permitted on this issue. Get specific provision made for this in the governing specifications as well as in the contract agreement.

(10) Insist on self-supporting scaffolds which do not require multiple on-going punctures in external walls for lateral stability. These form numerous seepage points later and, therefore, must be avoided.
Form work plays a very important role in shaping concrete quality during its placement and compaction. It must, therefore, be checked carefully for stability and good workmanship. Poor workmanship results in:

- (a) Cover variations for re-enforcement.
- (b) Loss of cement slurry during concrete placement and vibration.
- (c) Defective sub-structure prop arrangement can result in collapses.

Check list for form-work with safety and quality is, therefore, a must.

Check carefully cover thickness for concrete in R.C.C work in slabs, beams, columns. Fresh concrete is basically alkaline with PH ranging above 13. Cracks reduce PH values through seepage and attracts carbonation and other damaging salts. Combined effect accelerates corrosion damage seriously affecting durability of structure. Therefore, use pre-cast concrete blocks and concrete rings with holes to ensure proper cover.

All sub-contractors and their sub-agencies display scant regard for basic quality control like alignment, plumbness, quality of form work, curing, good workmanship etc., and are almost impossible to control. Therefore, work through these agencies should not be permitted.

Safety requirements on site are essential for engineer, supervisors, foremen, and all construction workers on the job. Inadequate safety and risk involvements is therefore certain to affect work quality as no one will go out of the way to risk his life in performing his day's work. Safety provision on construction work is, therefore a must and needs to be provided under contract conditions to enable quality level of work to be carried out and checked safely.

Another very common observation on construction sites is of workmen ruthlessly breaching structural elements at numerous places and to any extent, including cutting of re-inforcement to accommodate service conduits, pipes, other equipment by electrical sub-contractors, plumbers, and other workers. The watchful eye of the quality control supervisors must vigilantly and in timely manner stop such dangerous practices forthwith. In addition, the contractor must be severely reprimanded for such type of un-authorised activity and may even be penalised for damage caused to the structure by him/his workers.

Quality control supervisors on construction sites need very alert and watchful eyes to inhibit the contractor's aim to optimise his profits through malpractices of various kinds. Some typical ones are:

- (a) Application of used diesel oil in place of mould oil.
- (b) Use of waste paper slips instead of building paper and even mud plastering of gaps in form work.
(c) Use of broken tile pieces and sometimes stone aggregate pieces instead of cement mortar cubes or pre-cast holed concrete rings for concrete cover.

(d) Provision of chairs for re-inforcement provided only on repeated insistence.

(e) Placing concrete without electrical/mechanical vibrators on plea of having gone out-of-order and providing compaction with bamboo or steel rods called 'rodding'. This gives the contractor 4 to 5% less consumption of cement than with use of vibrators. This drama is repeatedly resorted by the contractor.

Quality control supervisors should act appropriately to nullify such like activities both firmly and promptly.

(17) Concrete is used as one of the most common construction materials. It is cheap and has immense flexibility. Due to this it is a badly handled construction product. In India, on majority of small and medium scale projects, it is of suspect quality, resulting in high incidence of concrete durability failures. Quality concrete construction possible only in adopting of a performance oriented approach, which requires strict supervisory care on the items listed below:-

(a) Cement required on site needs to be checked for (a) manufactured quality, (b) against adulteration. If found fit for acceptance, needs to be stored properly with the do's and don'ts of care.

(b) Ensure quality of water for mixing. Problematic waters are very harmful for concrete both during setting, hardening and volume stability of concrete. Waters not to be used are:

   (i) Water with high salt content (sea water)
   (ii) Containing sulphate
   (iii) Acidic water
   (iv) Containing organic substances
   (v) Highly turbid water
   (vi) Water containing algae

(c) Strict control of water-cement ration as specified by design office. Proper mechanism to ensure this needs to be devised.

(d) Sand used must be clean (without silt) and of the prescribed fineness modulus.

(e) Coarse aggregate must be of required quality, not be flaky and duly graded as prescribed by design office.
(f) Inspect forms carefully before placing concrete. Check correct location, correct elevation and dimensions, remove foreign materials (if any) from inside, ensure uniform concrete cover to reinforcement on all sides, also ensure no loss of cement slurry.

(g) Provide adequate on-going inspection during concreting by regular 'form watchers' for stability, settlement and proper displacement during vibrations. Signs of distress should immediately be rectified to avoid collapse.

(h) In placing, do not dump concrete in piles and then move it in position with vibrators, as this causes of ingredients.

(i) In placing, no concrete drop be more than 1.2 m. Use tremie chutes for higher drop areas.

(j) When external vibrators are used, these should be moved up and down. Do not under vibrate to avoid honeycombs nor over-vibrate to avoid segregation of mortar and aggregate.

(k) Curing is another most important, least expensive, yet frequently neglected item in concrete construction. Ensure strictly that this does not remain neglected. Poor curing seriously reduces the quality and strength of concrete.

5.2.10 Grid-Nodal-Matrix-Based Formulations: The Rationale for Intensive Quality Control.

In the Indian sub-continent the Grid-Nodal-Matrix formulation is a new innovative technical and scientific development in the art of building for mega-span structuring. It is a step towards induction of new architecture into the Indian firmament.

Normal structural concepts prevailing for short-span structures do not logically hold good for large span structure. Design details valid for 6-metre spans would not hold good for 20-metre span. Special design treatments have to be created in such structures—viz., permissible codal deflection will be tolerated by the structure, as well as by the user.

Floating columns, hidden beams, Grid-Nodal-Matrix-Based formulations and other make up systems for load transfer, do not conform to the established systems. They have different behaviour patterns, and as such need special attention both in the structural design phase, and in the construction procedures. It thus becomes incumbent upon the design professional to carefully monitor all important stages, i.e. in selecting the appropriate structural system, the computerised design calculations—taking carefully into account effects of fluctuating stress levels,
vibrations, atmospheric exposure, and secondary stresses generated due to several factors like impacts, structure size becoming more statically complicated, controlled deflections, stiffness and rigidity, well detailed reinforcement layout, form work contours and stability at erection stage and at the execution stage, to make the system durable and workable on long term basis.

In addition, the design must be build-able according to prevailing construction practices. It must be with in the scope of the contractor's competence, capabilities and limitations. Only then can a well-integrated and safe structure emerge.

The accidental death of a building is always due to the failure of its skeleton, i.e. the structure. With advancement of technology in the field of design analysis, with faster methods of computation by means of computer-aided design, the computer today is frequently used for refinement in their analysis. This point, however, is quite often inadvertently overlooked that quality control is also needed in the use of the computer tools viz.:-

(1) Improper data entry to an appropriate programme.
(2) Proper data entry into an in-appropriate programme.
(3) Appropriate programme with a previously unknown defect - a 'bug'.
(4) Permutations of the above.

About the construction site the design professional needs to be aware that technical and scientific developments in the art of building have not kept pace with the creative imaginative designer and the available construction methods for the new architecture innovation of the Grid-Nodal-Matrix-Based designs in the mega-span structure.

The design professional cannot afford to overlook, much less forget, that the structure created by him is expected to offer trouble-free serviceability to the user for a few decades. This cannot be achieved by sloppy-shoddy field work which nullifies elaborately-calculated designs incorporated in the drawings.

Another difficulty that confronts, the designer professional is that in the last 25 years there has been a virtual drain of the talented, trained, experienced and skilled artisans. The semi-skilled and un-skilled artisans became skilled and semi-skilled overnight. They are permitted to participate in the construction industry even for sophisticated work. Without adequate background and having hardly any training and basic technical knowledge, these artisans just make the structure without minimum performance standards. Thus quality is generously compromised.
The gap between the design and satisfactory execution has to be given serious thought, understood, bridged by a and suitable mechanism created to remedy the shortcomings.

What are the needed remedies that have to be planned and put into action?

5.2.11 Summary

A brief summary is catalogued hereunder which can prove effective:-

1. Workmanship is the first factor which influences the probability of collapse. It is, therefore, necessary in the new sophisticated mega-spanning Grid-Nodal-Matrix-Based architecture, work should be got carried out strictly by skilled artisans under qualified technical supervision.

2. In the design office greater risk potential areas (risk elements and locations) must be identified for inputs of efforts in design. This awareness would increase the needed attention within the profession to details of design rather than to more complex analysis. Required details are very necessary and must be provided with full professional competence.

3. In the sophisticated construction procedure which does not follow standard methods, pre-construction step-up-step written procedures must be outlined by the designer professional and carefully explained to the contractor for implementation.

4. Joints and their strength play an important role in the satisfactory functioning of the built structure. Prepare good working details of these joints. These must be as simple as easy in execution.

5. The entire system including architects, engineers and contractors must organise themselves to produce only good work in an interdependent team-effort at all stages, and should not leave any grey areas during execution.

6. Finally, in the innovative Grid-Nodal-Matrix-Based structure and architecture type under references, an overall high level and competent quality supervision becomes an absolute necessity to ensure that all the inputs in the projects work effectively without any grey areas, so that structure that is built gives trouble free service to the user— as a professional’s true compensation for his money.