Health monitoring and repair of a concrete shell roof structure

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Abstract. A Corrugated doubly curved sea shell form Concrete Structure of 70 mm thickness is functioning for the past 21 years, with good performance in an institutional building entrance hall of size 30m x 30m. The shell having only boundary beam; sloping to one diagonal corner at + 5 m level, the adjacent two opposite diagonal corners at +7 m level and the peak corner is at + 9 m level, supported by columns and footings are resting on rock. The designer has not taken care for thermal resistance performance and not checked for earth quake, and there was no maintenance except periodical cement based whitewash. But, it has performed well in an earthquake of Richter magnitude 4.0 and performing well for the climatic temperature variations ranging from 19⁰ C to 44⁰ C during the 21 years of life span. Vertical micro cracks were noticed in the boundary beams. Roof Shell is fixed with the boundary beams. The roof top surface is fixed with weathering ceramic tiles of size 25 mm x 25 mm bonded using tile bond branded chemical adhesive , has opened bonding in a period of five years in the higher deformation area. Hence, the observation was started by performance based health monitoring. Suitable smart materials were applied for surface skin coat to take care of the positive and negative stress-strains and deformations due to temperature variations. The static and dynamic stability against overturning, sliding and gravity forces is ensured adequate. The integral action of the system and the Elastic and Inelastic ductile behaviour of the shell are observed to be higher.

1 Introduction

Maintenance of concrete shell roof structure is highly important. Shells are thin and curved. Placing and compacting stiff concrete in curves is difficult. It causes durability in addition temperature expansion and construction problem is severe.

Prediction of thermal movement is also complicated. Non structures cracks are formed due to the above said problems. Inadequate or improper maintenance adversely affects the living comfort and environment.

Seismic force of rich scale & has caused opening of weather tiles of size 25 x 25 mm² temperature expansion also caused the opening of weather tile, it is ceramic called Kent tile in its brand. Micro cracks allow moisture to penetrate. Since shell is this corrosion and diteration problems are caused and it is continuous and progressive. Hence maintenance is very much essential cracks and collapse is the trouble in shells. Shells normally never give warning to collapse. So we have to repair and maintain regularly that is why, shell structures are rarely constructed. Only domes and vaults are common.

Our problem is a corrugated doubly curved shell form concrete roof structure unit in the entrance hall. It is 70mm thick. It is in an engineering college auditorium

entrance hall. The size in plan is 30m x 30m(Fig.1). The shell having only boundary beam; sloping to one diagonal corner at + 5 m level, the adjacent two opposite diagonal corners at +7 m level and the peak corner is at + 9 m level, supported by columns and footings are resting on rock.

National Building Code of India 2016 part-7 Section 5 Repairs, retro fittings and strengthening at buildings and sp25-1984 provide guidelines for repair and maintenance. This paper presents the assessment, repair over maintenance of the above said shell roof as per the NBC2016.

2 Structural condition assessment of the shell roof system

The Shell roof is fixed with the bounding by concrete deep beams supported by circular columns and a cluster of a circular columns in the lower corner support. The system is stable and the stability of the structural system is found correct.

The roof is very flexible because it is thin (70mm thick only); but the form is rigid. because of the anticlassical and syndicate and convaliine, funicular form and sloping to down corner and 2m cantilever in all

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the four sides and additional down tail- container cylindrical shell of 7m span in the single support(9 column cluster) as a counter balance.

Fig 1. Photograph of the constructed structure

Therefore the stability in the system is found perfect. the upper ip of the column supporting the boundary beams displace outward due to thermal expansion and reset to its original position on contraction since the temperature strain is very less, the structural and architectural elements are not subjected to distress or damage, but the roof it is square in plan with large spam of 30m x 30mx 0.01m it is subjected to repeated temperature expansion in deny and contraction in might with various climate conditions from summer to winter in this tropical climate location.

The repeated cycle of deformation causes slow cycle fatigue ,therefore regular periodical and continuous maintenance keeps this roof shell system perfect intact, water proof, no corrosion proof, no spalling of concrete, no deflection beyond to terence,

It is learned from this case study, they every shell roof structure should be maintained regularly with water proof and temperature strain resistance protective coating or painting or finishing. Since the percentage of shell to take care of temperature stress distribution only structurally stress in shell is least, it is taken care by structural concrete.

When this minimal Shell is corroded, Shell doest don't give warning to collapse, In this case of problem, expansion joint seating should have beam given with shell edge beam and proper seating material in the joint for friction release and expansion and contraction movement relaxation to avoid secondary stress and stress concentration in the boundary expansion joint.

3 Defects identified as per IS codes on shell roof structures

IS 2204 - 1962 and IS 2210 - 1988 are the two codes provide design and construction provisions for shell roofs based on the codal provisions the following facts are evaluated.

- Thickness maintenance is satisfied (thicker at the edge).
- Curvature maintenance is satisfied (perfect).
- Decentring from crown to edge without impact and should also verified from the construction specifications.
- Expansion joint is not provides (this is the reason for spreaded hair line and micro cracks in roof and vertical hair-line cracks in edge beams).
- Curing was done with gummy bag (jute bag) moist and covered on fresh concrete (perfect).
- Concreting with right vibrating, continuous concreting is done well.
- Maintenance was not done.
- Water proofing was done with cement and polymer based bonding mortar and joint finish sealant for the KENT ceramic weather proof tile
- Now elastic and ductile lime mixed sealant is provided to lower the thermal movement.
- Placing of reinforcement was perfect and not displaced during concreting.

Fig. 2. Photograph of boundary beam (edge beam) showing hair-line ,vertical cracks due to Thermal expansion

4 Cracks, diagnosis and repair in edge beams and roof

4.1 Boundary beams

- The cracks in edge beams are vertical Fig. 3. It is diagnosed as thermal expansion cracks due to boundary movement axial tensile stress in beams.
- During earthquake of Rectors' scale -4, the beams are not affected.
- The cracks are monitored and measured as shown in Fig4.
- As per I.S. code, Tell -tales consisting of strips of glass about 2 to 3 cm in width and 10 to 12 cm in length across the crack with quick setting adhesive was fixed. The shell - tale was no cracked. Hence it is found that the cracks are minor and within the tolerance level. The beam is not damaged.

Fig 3. Illustration of crack

4.2 The Shell roof

The shell roof was deforming with distributed micro cracks and hair-line cracks. It was due to both temperature movement and earth quake movement. Repair work was carried out with smart material and special technique. the banded weather tiles are open in the roof top surface is fixed with weathering ceramic tiles of size 25 mm x 25 mm bonded using tile bond branded chemical adhesive, has opened bonding in a period of five years in the higher deformation area.

Hence, the observation was started by performance based health monitoring. Suitable smart materials were applied for surface skin coat to take care of the positive and negative stress-strains and deformations due to temperature variations.

5 Conclusion

It was observed that special attention should be given in surface finish with suitable smart material and design for climate heat dissipation with idealised structural system for temperature stress relaxation to minimize structural damage repair to increase durability and serviceability.

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