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Advantage of High Strength Concrete in High Rise Buildings

Tatikonda. Prudhvi & CH.Ravi
[1]Pg Scholar,[2]Assosciate Professor
Department of Civil Engineering, Mother Teresa Institute Of Science And Technology,Sankethika nagar ,Sathupally-507303,Khammam(dist),Telangana State

ABSTRACT

The Advantage of High-Strength Concrete (HSC) in High-Rise Buildings: From Area Saving Aspect In recent years, the shortage and value of land in terms of cost and asset has increased the need to use land effectively and efficiently. This is more significant in High-Rise multi story buildings where small unusable dimension from each floor will accumulate and add up to huge loss of usable area. Based on this study, it has been concluded that, the area saved while using HSC to NSC columns and shear walls is more significant as the height of the building increases. The % decrease in concrete is higher, % decrease in reinforcement is lower and the total % decrease in cost is lower. Thus the higher the building, the amount of area and concrete saved is significant thus allowing the user to have more usable floor area leading to an economical use of land.

INTRODUCTION:

The definition of High-Strength Concrete (HSC) is subjective and varies on a geographical basis. In regions where concrete with a compressive strength of 62 MPa is already being produced commercially, High-Strength Concrete (HSC) might be in the range of 83 to 103 MPa. However, in regions where the upper limit on commercially available material is currently 34 MPa concrete, 62 MPa concrete is considered as High-Strength. Material selection, concrete mix proportioning, batching, mixing, transporting, placing, and curing procedures are applicable across a wide range of concrete strengths. Different literatures define High-Strength Concrete (HSC) as follows:- • "A High-Strength Concrete (HSC) is a concrete having a uniaxial compressive strength in the range of about 55 MPa to 138 MPa or higher." Arthur H.Nilson • "A High-Strength Concrete (HSC) is concrete which has a compressive strength greater than 50 MPa." RF. Warner • "Concrete with 28 day strengths in excess of 6000psi are referred to as High-Strength Concretes (HSC)." Mc.Gregor • "A High-Strength Concrete (HSC) is a concrete which has a compressive strength for design of 41 MPa or greater." ACI363R-92 In Ethiopia, according to EBCS-2, the highest compressive strength of concrete is given as 60 MPa.This thesis tries to investigate the advantage of using High-Strength Concrete (HSC) columns and shear-walls in buildings as compared with buildings with Normal-Strength Concrete (NSC) so as to increase net floor area. This advantage of HSC is found in different literatures in relation to various building elements. “In recent years, there has been a significant increase in the utilization of HSC with compressive strength in range of 50 to 100 MPa in columns and core walls of buildings. Use of HSC reduces the column construction coast and increases the net floor space available for use. ACI Committee 368 (1992) has indicated that using HSC with a minimum of longitudinal steel (i.e. 1 percent) is the most economical solution.” (RF Warner, 1999) “The most common application of HSC has been in the columns of tall concrete buildings, where normal concrete would result in unacceptably large cross sections, with loss of valuable floor space. It has been shown that the use of the more expensive HSC mixes in columns not only saves floor are but also is economical than increasing the amount of steel reinforcement.” (Nilson, 2010) “The expensive use of reinforced concrete construction, especially in developing countries, is due to its relatively low cost compared to other materials such as structural steel. The cost of construction changes with the region and strongly depends on the local practice. Even if it seems cheap, the cost of space that we sacrifice for the structural elements in high-rise buildings becomes very high, especially if long term benefit is evaluatedIf a specific objective criterion can be expressed mathematically, then optimization techniques may be employed to obtain a maximum or minimum for the objective function. Optimization procedures and techniques comprise an entire subject such as weight and cost. The criterion of minimum weight is emphasized throughout, under the general assumption that minimum material represents minimum cost. Other subjective criteria must be kept in mind, even though the integration of behavioral principles with design of structural steel elements utilized simple objective criteria, such as weight or space saving.” (Salmon, 2004). “Currently it was able to develop concrete with high compressive strength, up to 40 MPa and higher, which greatly helps in finding small structural element dimensions from design. Especially to build high-rise buildings by reducing column size and increasing available space, HSC plays a significant role (NRMCA 2001). In recent years, the application of HSC has increased and HSC has been possible as a result recent development

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in material technology and a demand for it, in relation to its space saving." (ACI 363R-92).

2.LITRATURE REVIEW

2.1.Historical background of High-Strength Concrete (HSC) The use and definition of High-Strength Concrete (HSC) has seen a gradual and continuous development over many years. Concrete with a compressive strength of 34 MPa was considered as High-Strength in 1950s. Whereas, in 1960s, concrete used in reinforced concrete construction had strengths in the range of 41 and 52 MPa. In the early 1970s, 62 MPa concrete was produced. Today, compressive strengths approaching 138 MPa have been used in cast-in-place buildings. As material technology and production processes evolve, it is likely that the maximum compressive strength of concrete will continue to increase and HSC will be used widely in different applications. Demand for and use of HSC for tall buildings began in the 1970s, primarily in the U.S.A. Water Tower Place in Chicago, IL, which was completed in 1976 with a height of 260 m and having columns and shear walls with compressive strength of 62 MPa. The 311 South Wacker building in Chicago, completed in 1990 with a height of 293 m, used 83 MPa specified compressive strength concrete for the columns. In their time, both buildings held the record for the world's tallest concrete building. Two Union Square buildings in Seattle, WA, completed in 1989, hold the record for the highest specified compressive strength concrete used in a building at 131 MPa. HSC is widely available throughout the world, and its use continues to spread, particularly in the Far and Middle East. All of the tallest buildings constructed have some structural contribution from HSC in vertical column and wall elements. Petronas Towers 1 and 2 completed in 1998 in Kuala Lumpur, Malaysia, used concrete with specified cube strengths up to 80 MPa in columns and shear walls both at 452 m. Taipei 101 in Taiwan, which was completed in 2004 has a total height of 509m. This structural system uses a mix of steel and concrete elements, with specified concrete compressive strengths up to 69 MPa in composite columns. All these height records have been suppressed by a taller building. The present record is held by the tallest building and the tallest structure of any type in the world, the Burj Khalifa in Dubai, United Arab Emirates, which has a total height of 828m.

2.2.Properties of High-Strength Concrete (HSC) Selection of Materials The production of HSC should meet the requirements of workability and strength than Lower-Strength

Concretes. HSC can be made using a wide range of carefully selected but widely available materials. These materials include, cement, aggregates, water and chemical or mineral admixtures. The choice of Cement for High-Strength Concrete (HSC) is extremely important. Furthermore, within a given cement type, different products will have different strength development characteristics because of the variations in compound composition and fineness. Strength development will depend on both cement characteristics and cement content. The use of high cement content will ordinarily produce higher ultimate strength. In general, however, no more cement should be used than necessary for required workability which is defined as the property of freshly mixed concrete which determines the ease and homogeneity with which it can be mixed, placed, compacted, and finished. Both Fine and Coarse Aggregates may be used in the production of HSC. According to ACI Committee Report 363R-92, fine aggregates with a rounded particle shape and smooth texture have been found to require less mixing water in concrete and for this reason are preferable in HSC. The optimum gradation of fine aggregate for HSC is determined more by its effect on water requirement than on physical packing. The requirements for Water quality for HSC are the same as those for conventional concrete. Usually, water for concrete is specified to be ofpotable quality. This is certainly conservative but usually does not constitute a problem since most concrete is produced near a municipal water supply. In addition to higher strength in compression, most other engineering properties of HSC are improved by the use of Chemical or Mineral Admixtures. Selection of type, brand, and dosage rate of all admixtures should be based on performance with the other materials being considered or selected for use on the project. Significant increases in compressive strength, control of rate of hardening, accelerated strength gain, improved workability, and durability are contributions that can be expected from the admixtures chosen.

2.3.Concrete mix proportions Concrete mix proportions for HSC have varied widely depending upon many factors. The strength level required, test age, material characteristics, and type of application have influenced mix proportions. In addition, economic considerations, structural requirements, manufacturing practicality, anticipated curing environment, and even the time of year do affect the selection of mix proportions. The selection of mix proportions can be influenced by the Testing Age. This testing age has varied depending upon the construction requirements.

Most often the testing age has been thought to be the age at which the acceptance criteria is established, for example at 28 days. According to ACI 363R-92 Committee Report, testing is conducted prior to the age of acceptance testing or after that age depending upon the type of information required. Early Age: - Pre-stressed concrete operations may require high strengths in 12 to 24 hours. Special applications for early use of machinery foundations,pavement traffic lanes, or slip formed concrete have required high strengths at early ages. Post-tensioned concrete is often stressed at ages of approximately 3 days and requires relatively high strengths. The optimum materials selected, and therefore the mix proportions, may vary for different test ages. Early-age strengths may be more variable due to the influence of curing temperature and the early-age characteristics of the specific cement. Therefore, anticipated mix proportions should be evaluated for a higher required average strength or a later test age. Twenty-eight days: - A very common test age for compressive strength of concrete has been 28 days. Performance of structures has been empirically correlated with moist-cured concrete cylinders, usually 6 x 12 in. (152 x 305 mm) prepared according to ASTM C 31 and C 192. This has produced good results for concretes within lower strength ranges not requiring early strengths or early evaluation. High-strength concretes gain considerable strengths at later ages and, therefore, are evaluated at later ages when construction requirements allow the concrete more time to develop strengths before loads are imposed. Proportions, notably cementitious components, have usually been adjusted depending upon test age. Later age: - High-strength concretes are frequently tested at later ages such as 56 or 90 days. High-strength concrete has been placed frequently in columns of high-rise buildings. Therefore, it has been desirable to take advantage of long-term strength gains so that efficient use of construction materials can be achieved. This has often been justified in high-rise buildings where full loadings may not occur until later ages.The relationship between water-cement ratio and compressive strength, which has been identified in conventional concrete, has been found to be valid for HSC. Higher cement and lower water contents have produced higher strengths. Proportioning larger amounts of cement into the concrete mixture, however, has also increased the water demand of the mixture. In proportioning a concrete mixture, it is generally agreed that the fine aggregates have considerably shown more impact on mix proportions than the coarse aggregates. The fine aggregates contain a much higher surface area for a given weight than do the larger coarse aggregates. Since the surface area of all the aggregate particles must be coated with a cementitious paste, the proportion of fine to coarse can have a direct quantitative effect on paste requirements. The optimum amount and size of coarse aggregate for given sand will depend to a great extent on the characteristics of the sand.

CONCLUSIONS Although HSC is often considered as relatively new material, it is becoming accepted in most parts of the world. At the same time, material producers are responding to the demands for the material and are learning production techniques. However, further work is needed to fully use the advantages of HSC and to affirm its capabilities. All materials for use in HSC must be carefully selected using all available techniques to insure uniform success. Mix proportions for HSC generally have been based on achieving a required compressive strength at a specified age. All materials must be optimized in concrete mix proportioning to achieve maximum strength. Required strength, specified age, material characteristics, and type of application have strongly influenced the mix design. HSC mix proportioning has been found to be a more critical process than the proportioning of NSC mixes. In the area of structural analysis and design, it has been found that axially loaded columns with HSC can be designed in the same way as NSC columns. The economic benefits of HSC are just now becoming fully apparent. Certainly as the use of HSC increases, additional and possibly even greater benefits will be realized. The above eight buildings have led the way in the use of HSC and have clearly demonstrated its economic advantages

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