Supplementary Cementitious Materials:

1. Silica Fume:

Silica fume is a by product obtained from the reduction of high – purity quartz with coal or coke and wood chips in an electric arc furnace during the production of silicon metal or silicon alloys. The use of Silica fume as admixture in concrete has opened up one more chapter on the advancement in concrete technology. More sticky mix can be obtained by addition of Silica fume in concrete. Using Silica fume in concrete increases its compressive, tensile, flexural and impact strengths and decreases permeability and bleeding.

Addition of silica fume in cement gives these advantages:

- It reduces bleeding of the concrete mix.
- It reduces segregation of the concrete mix.
- It aids the pumpability of the concrete.
- It may exhibit an increase in plastic shrinkage cracking.
- It reduces the permeability of the concrete.
- It increases density.

2. Fly Ash:

Fly ash is a fine powder that is a byproduct of burning pulverized coal in electric generation power plants. Fly ash is a pozzolan, a substance containing aluminous and siliceous material that forms cement in the presence of water. When mixed with lime and water, fly ash forms a compound similar to Portland cement. This makes fly ash suitable as a prime material in blended cement.

Use of fly ash in cement increases its workability, decreases bleeding and its air-entrainement is improved. At high levels problems may be encountered with extended set times and slow strength development, leading to low early-age strengths and delayed construction.

3. Rice Husk Ash:

Rice-husk (RH) is an agricultural by-product material. It constitutes about 20% of the weight of rice. It contains about 50% cellulose, 25–30% lignin, and 15–20% of silica. When rice-husk is burnt rice-husk ash (RHA) is generated. On burning, cellulose and lignin are removed leaving behind silica ash. The controlled temperature and environment of burning yields better quality of rice-husk ash as its particle size and specific surface area are dependent on burning condition. For every 1000 kg of paddy milled, about 200 kg (20%) of husk is produced, and when this husk is burnt in the boilers, about 50 kg (25%) of RHA is generated.

Its addition in cement imparts following advantages:

- It increases compressive strength of concrete.
- It decreases bleeding.
- Improves durability.

4. Sugarcane Bagasse Ash:

Sugarcane bagasse ash is abundantly available in Pakistan. It is obtained from sugar mills which use sugarcane bagasse as fuel. Sugarcane bagasse ash (SCBA) is obtained after using sugarcane bagasse as a fuel, resulting into non-usable material that is dumped in landfills and open streams thus causing environmental pollution. The use of sugarcane bagasse ash as partial replacement of cement not only improves the compressive strength of concrete but also improves the durability of concrete by reducing shrinkage and permeability.

In July 2015, Dr. Burhan Shareef along with two other researchers conducted a research on the suitability of sugarcane bagasse ash as a pozzolan. They calcined it at various temperature for various duration and found that best result were obtained when heating at 500 ^{0}C for 1 hour. It was also found that inclusion of reactive bagasse ash increases water demand of the mixture.

Types of Cements Used in Pakistan:

According to All Pakistan Cement Manufacturing Association **(APCMA)** he types of special cement now being produced can be roughly classified in the following six categories according to the special purpose for which these have been designed.

1. Rapid hardening cement.
2. Cement resistant to chemical attack of certain soil and aggregates.
3. Low heat of hydration cement.
4. Better protecting cement for steel reinforcement.
5. Better workability and whether resisting cement.
6. Decorative cement and other special cement.

1. Rapid Hardening Cement:

Under this category following two cement have the desired properties of fast development of strength. Their specific characteristics are as follows:

A. Rapid Hardening Cement (Type III of A.S.T.M):

This cement has high early strength, its equal to or better than 3 Days' strength of OPC. This is achieved by having high contents of tri-calcium silicates in its composition. It is mostly used in intended to release the framework within 24 hours or so for subsequent use in the mass production of RCC elements. The difference in strengths given above is basically due to difference in all standards the 3 days strength is nearly 1-1/2 to 2 times of O.P.C. The disadvantages of this cement beside its higher cost are its high heat of hydration, which renders it unsuitable for mass concreting projects.

B. High Aluminum Structural Cement:

This cement is used where very rapid setting and very high early strength are required. This cement has strength at one day nearly equal to 28 days strength of O.P.C. Its setting is so fast that it must be put in place within a few minutes of its mixing. It is generally used in plugging leakage in dams etc. or putting in pile foundations where limited time is available for setting of cement before the seepage water build up occurs. In Pakistan it has been used in some specific locations in terbela dam. Abroad it has been used in buildings where it was found essential to remove the framework after one or two days.

2. Cement Resistant to Chemical Attack of Certain Soil and Aggregates:

Cement resistant to chemical attack especially of Sulphate and Organic acids or Soil and active Silica of aggregate. In this category the following cement can be included:

A. Highly Sulphate Resisting Cement H.F.R.C:

The most important and the most widely used chemical resistant cement is H.S.R.C cement High concentration of sulphate salts is present in seawater and in the soil near seashores. These salts are sometimes present in soil and in the submit water even thousands of miles away from the sea. Even Terbela Dam site was found not free from sulphate and H.S.R.C had to be used in foundations at the site. The sulphate salt severally attack concrete can start within months. This cement has lower 3 days strength than OPC and also its capacity to protect reinforcement steel in structures exposed to atmosphere action is lower than OPC and hence not recommended for usual R.C.C. work in super structures.

B. **Moderately Sulphate Resisting Cement (M.S.R.C.):**

This cement has been developed as a compromise Cement having the good properties of sulphate resistance to some extent and of good alkalinity like that of OPC which useful for reinforcement protection and also of early strength development better than Highly Sulphate Resisting Cement. No standard exists for this cement in the B.S and P.S. specifications but under ASTM it is designed as Type II. The three days minimum strength of OPC, H.S.R.C & H.S.R.C is 1800, 1200 and 1500 PSI respectively under ASTM.

C. Low Alkali Cement:

This is a variety of ordinary Portland cement in which the total alkali contents of cement has been controlled to remain below 0.6%. With this reduced percentage of alkali contents the danger of alakie of cement attacking the active silica contents of aggregate is eliminated. Generally we do not have active aggregate of this type in Pakistan but on each large scale-concreting project, test of alkali aggregate reaction must be performed to enshore safety of the project. Certain varieties of Chert-stone found in Pakistan contain active Silica and would require low alkali for making concrete.

3. Low Heat of Hydration Cement:

Normal and Rapid Hardening Cement generate lot of heat during the setting and hardening process so much so that the structure under concreting can crack. This can occur specially while poring large messes of concrete in confine spaces like those of Dam and Bridge pier foundations. In order to avoid this problem cement of low Heat of hydration have been developed some of which are as listed below:

A. Low Hear of Hydration Cement (type IV of A.S.T.M.):

This is cement specially meant for the concreting of structures where large masses of concrete have to be poured at one time. Generally it is specified that heat of hydration on 7 days will not exceed 250Kg. This is achieved by making this cement with larger percentage of di-calcium silicates in its contents than normally presents in OPC. In A.S.T.M this cement is designated as type IV and under BS as LHP. Under German standards its type is LAHORE with symbol as N.W. while the Japanese equivalent is type L.H.P with symbol as M.H.C. The disadvantage of this cement is its slow development of strength and is therefore not used at sited where rapid hardening or other specific qualities are required.

B. Super Sulphate Cement:

This is another variety of low heat cement. Its standards exist under B.S but not under A.S.T.M. it is made by grinding about 70-80% B. F. Slag with about 10% gypsum and 1-2 % Portland clinker or lime. This cement is also middy resistant to sulphate attack. It is very finely ground cement and its early strength at 3 day is comparable to OPC although under the BS its 7 days strength is required to be comparable to at least the 3 days strength of OPC. This cement is also good masonry cement due to its good workability but it can be used in RCC and other construction work in the same manner as OPC is used with excellent results.

4. Cement for Better Protection of Reinforcement Against Corrosion:

The basic steps for the prevention of resulting of steel in concrete is to use such cement aggregate and mixing water as are basically free from chlorides, maximum contents of chlorides in concrete being limited to 0.02 % by weight. The following properties in cement are essential for greater protection of steel:

1. Cement to be with minimum percentage of Chlorides says not exceeding 0.01 per cent.
2. Portland Cement preferably having about 6 to 8 per cent Tricalcium Aluminates.
3. Cement made with slag as additive.

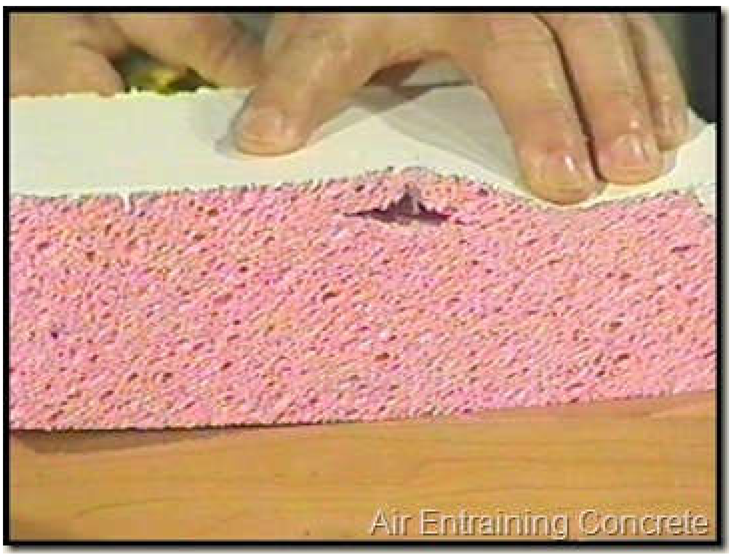
If the Tricalcium Aluminates is less than 5 per cent as per ASTM the cement will not have the capacity to neutralize the stray Chloride entering into concrete and thus fail toward off the effects of Chlorides. The properties of slag cement with about 35 percent slag and 60 per cent Portland Clinker are superior to other cement in this respect.

5. Cement for Better Workability and Wealth E.W. Resistance:

These are cement, which are render the corresponding concrete more workable than other normal cement. This quality is necessary where high compatibility and better weather resistance is demanded. Because of greater workability the concrete made from this cement can achieve much higher strength due to lower water cement ratios achievable compared with other cement.
This property is given to the cement by addition of the entraining agents like lime or other plasticisers so that the remix and to place in position. Some of the cement belong to this category are:

A. Air Entraining Cement:

Under ASTM four different types of cement have been classified as air-entraining version for normal Rapid-hardening and Sulphate Resisting Cement and each concrete thus made is more workable and attains higher weather resisting property compared to their non-air entrained versions.



B. Blended Hydraulic and Masonry Cement and Grouts:

This cement is basically made for plastering and grouting. Standards have been laid down for this cement both in the British and ASTM specifications. In fact under ASTM there are at least 10 versions of Masonry cement. Some of the standards are for OPC based cement with or without air entraining agents while others are for sulphate resistance and low heat versions. This masonry cement is made by addition of plasticizing materials like lime, ground silica, slag or Pozzolana and air- entraining agents' etc. Portland Cement clinkers during grinding.

6. Decorative Cement Oil Well and Other Special Purpose Cement:

This cement is basically of properties similar to O.P.C except that it is made from such raw materials, which contain the least amounts of coloring pigments like traces of iron, manganese and chrome. Basically this cement has higher Tricalcium Aluminates in its contents than OPC and therefore subjects to sharp attack by sulphate from any source.