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Technical Paper

# Influence of Hydroxypropyl Guar on Water Retention of Cement Based Renders

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**Abstract:** Cellulose ethers are polymers introduced into mortar formulations to improve thickening and water retention capacity. Cellulose industry require technology with chemicals treatment which causes the production of industrial wastewater and made this industry for one of the largest pollutants of water and air. This work present the analysis of possibile application of the guar beans powder in cement based renders for partical replacement of the cellulose ether. Technology of basic guar bean powder production is very simple process and present only mechanical operations which don't include a chemical treatments that causes pollutant effects to ecology. Experimental part involves a meassurement of water retention capacity in freshly mixed cement based render independency of quantity of aplicient hydroxypropyl guar. For measuring are Filter plates and conical plastic rings according to EN 459-2 were used for measurements. The results are presented as mass percente of hydroxypropyl guar (HPG) which can be replaced with hydroxyethyl methyl cellulose (HEMC) including high water retention capacity in optimal conditions of used water for preparing fresh mixed mortars. Thereby, the possibility for decraseing consuption of celluloseused in t building material products and constructions has been established which can improve a positive effect by decreasing wood exploatation and decreasing enviromental pollutants.

## INTRODUCTION

Factory-made mortars are mainly composed of mineral binders (cement or gypsum and hydrated lime), aggregates and fillers. They also contain different kinds of additives, mostly organics (polysaccharides), in order to impart some specific properties to the mortar, from the fresh paste to the hardened material. Among all polysaccharides, cellulose ethers seem to be the most suitable molecules to produce mortars with very high water retention ability (higher than 97 %). When mortar is applied to substrate, water may be absorbed by the substrate which can induce insufficient hydratation of cement and thus decrease a mechanical properties of the mortar.

Among all polysaccharides, cellulose ethers are able to improve excellent thickening, water retention capacity and workability of fresh mixed mortar. Water retention is a fundamental property, which affects workability and bonds between mortar and masonry (Patural et al, 2011).

The most widespread cellulose ethers used in practice for mortar's formulations are hydroxypropyl methyl cellulose (HPMC) and hydroxyethyl methyl cellulose (HEMC). The cellulose industry is one of the most serious produces of environmental pollutants because of the nature of technological process. The production of basic technical cellulose involves a chemical treatments which results in a production of a different chemical waste.

The guar plant (*Cyamopsis tetragonoloba* L.) is source of natural polysaccharide found in the seeds. Technological process of basic guar gum production is simple and involves only mechanical steps. The plants have the capability to produce basic guar, modified ethers, cationic guar as well as other single and mixed derivates. Guar beans grow in pods which are three to five centimeters long and consists of three main components, the seed coat, the endosperm and the cotyledon. The endosperm accounts for about one third of the bean weight and contains the majority of the polysaccharide (galactomannan).

Basic guar is produced by a process in which the bean splits are hydrated and then milled under high pressure and shear conditions that provide efficient rupturing of the cell walls and release the galactomannan content. After the initial milling stage, the product is dried and reground to produce the basic guar gum powder.

Hydroxypropyl guar (HPG) is one of the guar ethers which is produced by etherification of highly pure guar with base and propylene oxid. HPG is nonionic product which is soluble in cold water and forms thick solutions at low concentrations The molecular structures of basic guar gum and HPG are shown on Figure 1.

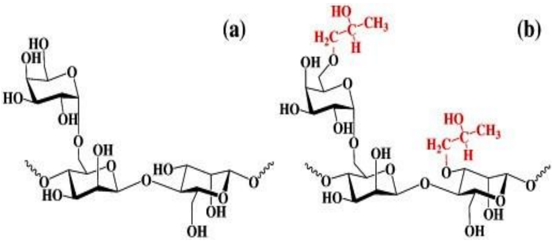


**Figure 1**: Molecular structures of basic guar gum (a) and HPG (b)

HPG have good thickening property and water retention capacity and can be partially replaced with quantity of cellulose which is used in mortar formulations as a thickener and water retention agent. In this work we used well known recipe and additives in order to produce a mortars with known quality and very high water retention capacity.

## EXPERIMENTAL

The renderer has been used in experiment in order to provide adequately consistence and workability of freshly mixed mortar as well as granulometry of aggregates and filler according to Fuller granulometry curve to produce mortar without empty spaces between aggregates.

Amount of 1kg mortar were prepared for each measurement of cement based render. For preparing freshly mixed mortar, water requirement should be optimum, between 20-25%, to provide adequate consistency for workability.

### Preparation of dry cement based render

For preparing dry cement based render, portland cement CEM I 52,5 N (properties according to EN 197-1 : 2005 ) and hydrated lime CL 80 S (properties according to EN 459-1:2010) have been used.

**Table 1:** Properties of CEM I 52,5 N

| Parameters | Properties |
|---|---|
| $SO_3$ | 3,0 % |
| $Cl^-$ | 0,0005 % |
| Loss on ignition | 1,3 % |
| Insoluble residue | 1,0 % |
| Initial setting time | 150 min |
| Soundness (Le Chatelier) | 0,8 mm |
| Compressive strength/28 days | 58 MPa |

**Table 2:** Properties of hydrated lime CL 80 S.

| Parameters | Properties |
|---|---|
| CaO+MgO | 3,0% |
| MgO | 0,81% |
| $CO_2$ | 1,3% |
| $SO_3$ | 1,0% |
| Free water | 150 min |
| Soundness (Le Chatelier) | 0,8 mm |
| Penetration | 26 mm |
| Air content | 3,3% |

Limestone sand 0,8 – 1,4 mm and 0,0 – 0,125 mm, have been used as aggregates and filler whose properties are given in Table 3.

**Table 3:** Chemical composition of limestone sand and filler.

| Parameters | % |
|---|---|
| CaO | 53,61 |
| MgO | 1,66 |
| $Cl^-$ | 0,0006 |
| $SiO_2$ | 0,45 |
| $R_2O_3$ | 0,51 |
| Loss on ignition | 43,57 |
| Free water | 0,04 |

HEMC and HPG have been used for thickening and water retention capacity.

**Table 4:** Properties of HEMC.

| Parameters | Properties |
|---|---|
| Appearance | white powder |
| Viscosity | 20,000-27,000 mPa*s |
| Particle size | <125µm: min 90% |
| Moisture | < 7 % |
| Water retention | 98,8 % |

**Table 5:** Properties of HPG.

| Parameters | Properties |
|---|---|
| Appearance | beige powder |
| Viscosity | 3 000- 6 000mPa*s |
| Particle size | <125µm: min 85% |
| Moisture | < 3 % |
| Water retention | 92,7 % |
| pH (2 % solution) | 7,1-8,9 |

Starch ether for slip resistance and air entraining agent have been used for preparation of dry mortar whose properties are given in Table 6 and 7.

Dry cement based render is prepared in order to produce freshly-mixed mortar which can provide very good quality of rheological requirements and workability.

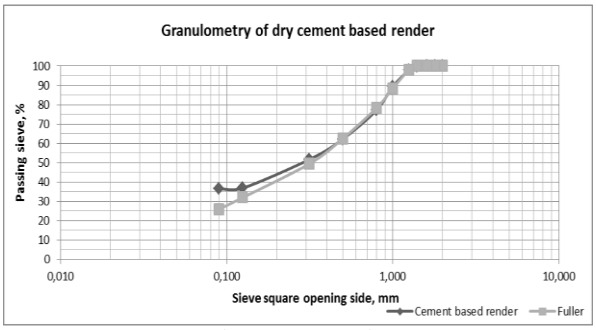


**Figure 2:** Composition of aggregates and filler.

Granulometry is determined according to Fuller's curve of aggregates for cement concretes in order to provide optimal composition of aggregates and filler.

**Table 6:** Properties of starch ether.

| Parameters | Properties |
|---|---|
| Appearance | powder |
| Oleinic sulphonat | 90-98 % |
| Potassium carbonate | < 5 % |
| pH | 10-11 |
| Bulk density | 300g/L |

**Table 7:** Properties of starch ether.

| Parameters | Properties |
|---|---|
| Appearance | powder |
| Viscosity | 20 mPa*s |
| Particle size | <125µm: min 60% |
| Moisture | 4 % |
| Bulk density | 600g/L |

The recipe which is used for preparing cement based render is given in Table 8.

**Table 8:** The recipe for preparing dry cement based render

| Composition | % |
|---|---|
| Portland cement | 12 |
| Hydrated lime | 6 |
| Filler | 7 |
| Limestone sand | 65 |
| Thickener and WR agent | 0.12 |
| Starch ether | 0.025 |
| Air entraining agent | 0.025 |

**Preparation of freshly mixed mortar and measuring of water retention**

Freshly mixed mortars have been prepared with enought amount of water in order to produce consistency which flow diameter's value is 170 ± 3 mm. In this way good workabillity and apllication of material at surface have been provided , as well as sufficient hydration of the cement. For determination, a sufficiente quantity of water as a thickener in the recipe is used together with HEMC with zero composition of HPG to provide determination the variety of consistency and water retention capacity dependency of quantity of aplicient HPG.

The amount of water has been placed into laboratory mixer and mixed, then the timer was started and dry mortar placed into mixer during first 10 sec. Mixture was continuously mixied in period of 60 seconds. After mixing was finished, mortar was placed into mould in order to determined the flow diameter according to EN 459-2. When the required flow diameter has not been achived with the selected amount of water, the correct amount of water was determined by using other mixtures with different quantities of water. Freshly mixed mortar with correct consistency has been used for measuring of water retention.

For determining the water retention filter paper plate (190 mm x 190 mm x 2 mm), conical plastic ring ( 140 mm smaller and 150 mm larger inside diameter, 12 mm in height) , two plastic plates ( 200 mm x 200 mm x 5 mm ) and nonwoven tissue according to standard have been used.

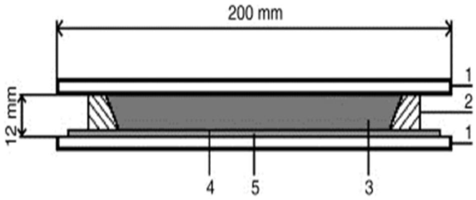


**Figure 3:** Apparatus for water retention measuring according to standard EN 459-2 (1- plactic plate, 2- conical plastic ring, 3- freshly-mixed render, 4- nonwoven tissue, 5- filter plate).

Water retention of the freshly mixed render is expressed as that percentage of water which remains in the mortar after short suction time on filter paper.

Water retention (WR) was calculated following formulations according to the EN 459-2:

$$WR = 100 - W_4$$

$$W_4 = \frac{m_{20} - m_{17}}{(m_{19} - m_{18}) \text{ x } \left(\frac{m_{21}}{m_{21} + m_{22}}\right)} \text{ x } 100\%$$

where $W_4$ is the relative loss of water after suction time, $m_{21}$ is the total mass of water in fresh mortar, $m_{22}$ is the mass of dry mortar, $m_{23}$ is the mass of mortar in the plastic ring, $m_{20}$ is the mass of the soaked filter plate and the plastic plate, $m_{19}$ is the mass of the plastic plate, filter plate, nonwoven tissue and plastic ring with mortar filling, $m_{18}$ is the mass of the plastic plate, filter plate, nonwoven tissue and plastic ring.

## RESULTS AND DISCUSSION

Freshly mixed render with HEMC prepared with correct consistency for workability and parameters was measured in order to provide observation of parameters variabillity dependency of quantity apllied HPG. Water retention has been mesured twice at each sample of freshly mixed mortar and avarege is used as the result. Following the increase of applied HPG which is replaced with HEMC correlation between consistency and water retention capacity has been detected. The results demonstrated that the increase of HPG has effect on dimeter's value of consistency and the water retention capacity of freshly mixed render decreasing both values. This also have influence on workabillity and application of material at the surface, which is shown in Table 9.

**Table 9:** Results of water retention measuring

| HPG % | Water % | Consistency mm | WR % |
|---|---|---|---|
| 0 | 22.5 | 170 | 98.8 |
| 5 | 22.5 | 170 | 98.6 |
| 10 | 22.5 | 170 | 98.3 |
| 15 | 22.5 | 169 | 98.1 |
| 20 | 22.5 | 168 | 98.0 |
| 25 | 22.5 | 168 | 97.8 |
| 30 | 22.5 | 168 | 97.5 |
| 35 | 22.5 | 167 | 97.2 |
| 40 | 22.5 | 166 | 97.0 |
| 45 | 22.5 | 165 | 96.6 |
| 50 | 22.5 | 165 | 96.2 |
| 55 | 22.5 | 164 | 96.0 |
| 60 | 22.5 | 163 | 95.8 |
| 65 | 22.5 | 161 | 95.4 |

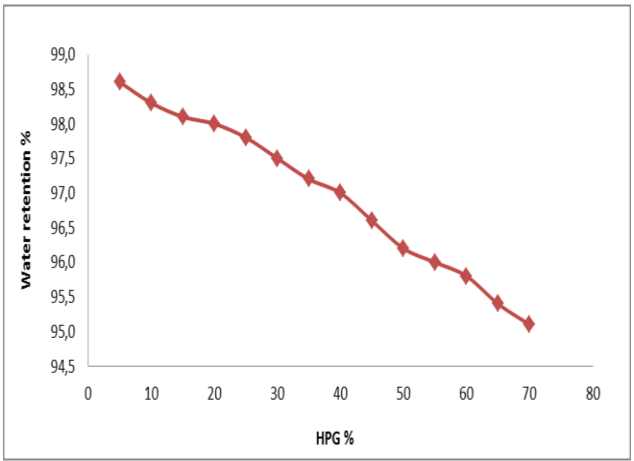

**Figure 3:** Water retention of freshly mixed cement based render-

## CONCLUSION

The conclusion of this study is that HPG as a product of guar gum plant can be used as an additive in building materials. About 25-30 % of cellulose ether in cement based render can be replaced with HPG at conditions of optimal demand of water for preparing freshly mixed mortars. This quantity of HPG is acceptable for consistency and workability of freshly mixed mortar as well as water retention capacity wich is higher than 97 %.

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## Summary/Sažetak


Celulozni eteri primjenjuju se u proizvodnji mortova kao učvršćivač i sredstvo za retenciju vode svježe pripremljenog morta, što olakšava obradu materijala. Sama proizvodnja tehničke celuloze zahtijeva tehnološki postupak obrade kemikalijama, što industriju celuloze čini jednom od najvećih zagađivača vode i zraka. Cilj ovog rada je analizirati mogućnosti primjene sjemena guara u cementnim mortovima kao djelomičnu zamjenu za celulozu. Obzirom da proces proizvodnje primarnog oblika guarovog praha uključuje samo mehaničke postupke, bez tretiranja kemijskim supstancama, sam proces nema negativan utjecaj na okoliš. U eksperimentalnom dijelu primijenjen je eterificirani oblik guara, hidroksipropil guar (HPG), kao zamjena za hidroksietil-metil celulozu (HEMC). Rezultati obuhvataju mjerenje sposobnosti retencije vode u cementnom malteru u odnosu na količinu primijenjenog HPG u optimalnim granicama zahtijeva za vodom suhog morta. Za mjerenje retencije vode korištene su filter ploče i kalupi prema propisanoj normi. Rezultatima analiza ustanovljena je granična količina HPG koja se može zamijeniti sa HEMC , a da se pri tome zadrži visoka retencija vode (> 97 %) i zahtjev za konzistencijom ostane u optimalnim granicama u odnosu na količinu dodane vode. Na ovaj način dat je uvid u mogućnosti primjene biljke guara kao aditiva u proizvodnji građevinskih mortova, što ima pozitivan utjecaj na smanjenje eksploatacija šumskih površina i zagađenja okoliša uzrokovanog otpadnim tvarima iz industrije celuloze.